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(54) BROADBAND SPIRAL ANTENNA

(71) We, TRANSCO PRODUCTS, INC., a corporation organised under the laws of the State of California, United States of America, of 4241 Glencoe Avenue, Venice, County of Los Angeles, State of California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention is directed to a broadband spiral antenna and specifically to a broadband spiral antenna including additional antenna elements to extend the low frequency response of a planar, equi-angular or Archimedean spiral antenna element. Specifically, the present invention provides for the extension of the low frequency response of the spiral antenna element by terminating the outer end of the arms of the spiral such as a planar spiral with a series of folded dipoles extending around a tubular member.

It is often desirable to try to encompass within a single antenna structure a very broadband frequency response in a relatively small space. For example, radar warning systems have historically been characterized by steadily increasing band widths and ever expanding frequency limits. Since these radar warning systems must exhibit the high probability of intercept over broad frequency ranges, their antennas must provide adequate gain and stable patterns over these wide band widths. In addition, it would be desirable to have only one antenna cover the entire system frequency range. Specifically, it would be desirable to provide for a single antenna structure providing a broad frequency range such as 0.5 to 18 GHz.

One particular design for such a broadband antenna structure has been proposed in an article entitled "New Spiral-Helix Antenna Developed" which article was written by John W. Greiser and Marvin L. Wahl and which appeared in the May/June 1975 issue of *Electronic Warfare* Magazine. The antenna structure proposed and described in this article included a spiral radiator with a bifilar helix to provide for a circularly polarized antenna to cover the 0.5 to 18 GH_z bandwidth in a single antenna structure.

The present invention is defined in the appended claims to which reference should now be made.

An embodiment of the present invention will now be described with reference to the accompanying drawings, wherein:

Figure 1 is a perspective view of the top and one side of an antenna embodying the present invention;

Figure 2 is a perspective view of the bottom and another side of the antenna of Figure 1;

Figure 3 is a top plan view of the spiral antenna portion of the antenna of Figure 1;

Figure 4 is a side view of one side of a folded dipole portion of the antenna of Figure 1; and

Figure 5 is a view of the folded dipole portion of Figure 4 flattened out to show the entire dipole structure.

In Figure 1, a perspective view of the top and one side of the antenna structure shows a cylindrical member 10 closed at both ends to form a cavity. One end of the cylindrical member 10 is closed with a flat plane member 12 supporting a planar spiral having a pair of spiral arms 14 and 16 spiralling outwards from a center feed portion to outer arm portions 18 and 20. A top view of the planar spiral is shown in Figure 3 to include the spiral members 14 and 16 and the outer arm portions 18 and 20.

The other end of the cylindrical member 10 is shown in Figure 2 to be closed by a flat member 22 and extending from the flat member 22 is a short cylindrical portion 24 having a closed end for supporting a coaxial connector 26. A side view of the antenna is shown is Figure 4 and additionally in Figure 4 is shown in dotted lines a balun 28 located within the cylindrical members 10 and 24. The balun 28 is used to convert the resistance of the coaxial input connector 26 at the bottom of the antenna structure to a balanced impedance of the proper resistance at spiral feed points at the center of the spirals 14 and 16. The spiral feed points are designated by reference characters 30 and 32 as shown in Figure 3.

Specifically, the balun may convert the normal 50 ohm coaxial input impedance to a balanced impedance of approximately 120 ohms at the spiral feed points 30 and 32. As shown in Figure 4, the balun is located along the axis of the cylindrical members 10 and 24 and is contained totally within the cylindrical members. It is to be appreciated that any appropriate balun structure or other impedance matching structure may be used.

The cylindrical members 10 and 24 and the plate member 12 are normally formed of dielectric materials and the spiral members 14 and 16 are formed of metallic material. Specifically the spirals 14 and 16 may be formed as a printed circuit on the dielectric plate. Attached to the outer arm portions 18 and 20 of the planar spiral members 14 and 16 are two metallic folded dipole arrays that continue the planar spiral arms along the outer surface of the dielectric cylindrical member 10. In Figure 5 the metallic array patterns for the folded dipoles are shown flattened out. In addition, Figures 1, 2 and 4 illustrate various side views of portions of the dipole array patterns. The dipole array patterns may be seen to include a first metallic pattern 50 including five folded dipoles 52 to 60 of progressively larger size and extending circumferentially around the cylindrical member 10 along a generally helical path. A second metallic conductor pattern 62 includes four folded dipoles 64 to 70 also extending along a generally helical path circumferentially around the cylindrical member 10.

Generally all of the folded dipoles are of the series type wherein current enters the top of a folded dipole element, follows a path through the dipole element and exits from the lower conductor portion of the dipole element in order to proceed to the next folded dipole element. The lengths of the folded dipole elements increase with the distance from the attachment point to the planar spiral members 18 and 20 so that in a particular example the resonance frequencies of the dipoles range from approximately 1.9 GHz to 0.6 GHz. It can be seen, therefore, that the folded dipoles extend the low frequency range of the planar spiral elements to increase the overall frequency range of the entire antenna structure.

While the lengths of the individual dipoles 52 to 60 and 64 to 70 in the arrays determine the frequencies at which each individual dipole has its maximum radiation, the antenna also includes an independent means to control the phase progression of the dipoles. Generally, in order to provide for a circular polarization radiation pattern from the folded dipoles, it is necessary to have both space (geometric) and phase (time) quadrature. Space quadrature is achieved by disposing the dipole elements around the dielectric cylindrical member 10 in approximately 90° intervals. The phase quadrature is achieved by shorting across the dipole arms symmetrically on either side of the feed points. This phasing technique by shorting across the dipole arms provides for enhanced performance of the antenna. As shown for example in Figure 5, the arms of dipole 52 are shorted at points 72 and 74 so that while the current path is shorted the radiation occurs over the entire length of the dipole elements. It can be seen that each folded dipole is shorted in a similar fashion.

The lower ends of the two conductor lines 50 and 62 are terminated by two resistors 76 and 78 which terminate any energy that has not been radiated by the antenna structure. The use of the resistors 76 and 78 improves the radiation pattern and the VSWR performance at the lower end of the range of the frequency band. As shown in the drawings, each resistor 76 and 78 may be disposed in a recess in the dielectric cylindrical member 10. As an alternative, the resistors 76 and 78 may be formed from a resistive material disposed in a plane on the surface of the dielectric cylindrical member 10.

It is to be appreciated that the specific embodiment as described in this application relates to the provision of a frequency range from approximately 0.5 to 18 GHz but that other frequency ranges may be covered by making the overall antenna structure larger or smaller. In addition low frequency patterns and gains can be altered by increasing or decreasing the length of the dipole array. Also different numbers and arrangements of the folded dipole radiators may be used in place of the specific number and arrangement shown in the present application. It is also to be appreciated that other types of dipoles could be used in place of the series fed, folded dipoles shown. For example, shunt dipoles, folded tripoles, and Windom dipoles could also be used in place of the specific series fed, folded dipoles illustrated. It is also to be appreciated that an antenna embodying the present invention may be constructed using printed circuit techniques so that all portions of the structure are formed as a printed circuit structure. In addition, various types of RF absorbing material may be located within the dielectric cylindrical member 10 so as to suppress back radiation from the planar spiral and to prevent reflections from the balun structure 28.

It can be seen, therefore, that the broadband antenna structure illustrated uses a broadband planar spiral element of the Archimedean or equi-angular type coupled to a cylindrical array of series fed dipole elements. The planar spiral radiates a circularly polarized field above its lower cutoff frequency and the cylindrical array radiates a circularly polarized field below the lower cutoff frequency of the planar spiral. The cylindrical array of dipole elements may consist of two sets of series fed, folded dipole elements with the two sets connected to the outer ends of the planar spiral arms. The individual dipole elements of each set may be spaced at approximately 90° intervals around a dielectric tube member supporting the series fed, folded dipole elements and with the dipole elements generally following a helical path from the top of the tube to the bottom of the tube.

The dipole structure is designed to produce a backfire radiation pattern over a range from the normal low frequency cutoff of the spiral antenna element to a lower frequency such as two octaves or more below the normal low frequency cutoff of the spiral antenna element.

The spiral element portion of the antenna, which is shown as a planar spiral, operates in a normal fashion above the low frequency cutoff. The dipole arrays do not contribute to the radiation field above the low frequency cutoff of the spiral element because currents on the spiral arms are attenuated to small values by radiation. Therefore, above the low frequency cutoff the dipole structure does not affect the operation of the planar spiral. Near the low frequency cutoff of the planar spiral element both the planar spiral and the dipole structure radiate circularly polarized fields. Low pattern axial ratios are maintained by the antenna because the dipole structure represents a low reflection coefficient to the spiral arm currents, thereby greatly reducing the end effect or reflections from the outer ends of the spiral arms. As the frequency response is reduced further, the spiral element does not provide for any significant radiation and the spiral element functions as a transmission line section to feed the dipole structure. The dipole arrays, therefore, are the main radiators below the normal low frequency cutoff of the spiral antenna.

The illustrated structure has a broadband frequency response and several advantages over the prior art designs including that described in the article referred to above. Specifically, the antenna structure of the present invention has a higher gain and low VSWR than that proposed in the article in *Electronic Warfare* Magazine referred to above.

WHAT WE CLAIM IS:-

1. A broadband spiral antenna including a tubular member having a planar surface at one end,

a planar spiral antenna portion supported on the planar surface and spirally outward from a central position on the planar surface to an edge position on the planar surface, and

an array of dipole elements supported on and extending around the tubular member and coupled to the planar spiral antenna portion at the edge position.

2. A broadband spiral antenna according to claim 1, wherein the array of dipole elements is an array of series fed, folded dipoles of unequal lengths.

3. A broadband spiral antenna, according to claim 2, wherein each folded dipole is symmetrically shorted across its arms for providing phase quadrature.

4. A broadband spiral antenna according to claim 1, wherein the tubular member is cylindrical and the array of dipole elements extend around the tubular member along a helical path.

5. A broadband spiral antenna according to claim 1, wherein the planar spiral antenna portion includes a pair of spiral arms spiralling outwards to a pair of edge positions and with a pair of arrays of dipole elements coupled to the spiral arms at the edge positions.

6. A broadband spiral antenna according to claim 5, wherein the pair of arrays of dipole elements are each an array of series fed, folded dipoles of unequal lengths.

7. A broadband spiral antenna according to claim 6, wherein each folded dipole is symmetrically shorted across its arms for providing phase quadrature.

8. A broadband spiral antenna according to claim 5, wherein the tubular member is cylindrical and the pair of arrays of dipole elements extend around the tubular member along a helical path.

9. A broadband antenna, including,

a cylindrical member having a closed surface at one end,

a spiral antenna portion disposed on the closed surface and spiralling outwards from a central position to the circumference of the cylindrical member, and

an array of dipole antenna elements coupled to the apiral antenna portion at the circumference and disposed on and extending around the cylindrical member.

10. A broadband antenna according to claim 9, wherein the array of dipole antenna elements is an array of series fed, folded

dipoles of unequal lengths.

11. A broadband antenna according to claim 10, wherein the individual dipole antenna elements are spaced at approximately 90° intervals around the cylindrical member.

12. A broadband antenna according to claim 10, wherein each folded dipole is symmetrically shorted across its arms for providing phase quadrature.

13. A broadband antenna according to claim 9, wherein the dipole antenna elements extend around the cylindrical member along a helical path.

14. A broadband antenna according to claim 9, wherein the spiral antenna portion includes a pair of spiral arms spiralling outwards to spaced circumferential positions and with the array of dipole elements formed as two sets of dipole elements and with sets coupled to the spiral arms at the circumferential positions.

15. A broadband antenna according to claim 14, wherein each set of dipole elements is an array of series fed, folded dipoles of unequal lengths.

16. A broadband antenna according to claim 15, wherein the individual dipole elements in each set are spaced at approximately 90° intervals around the cylindrical member and wherein each set of dipole elements is spaced from the other set of dipole elements.

17. A broadband antenna according to claim 16, wherein each set of dipole elements extend around the cylindrical member along a helical path.

18. A broadband antenna according to claim 17, wherein each folded dipole element in each set is symmetrically shorted across its arms for providing phase quadrature.

19. A broadband spiral antenna substantially as described hereinbefore with reference to the accompanying drawings.

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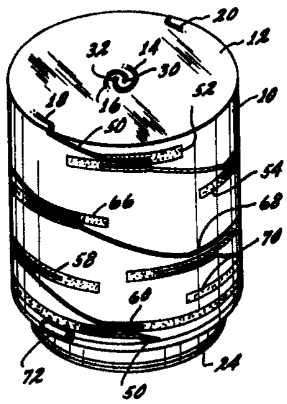

Fig. 1

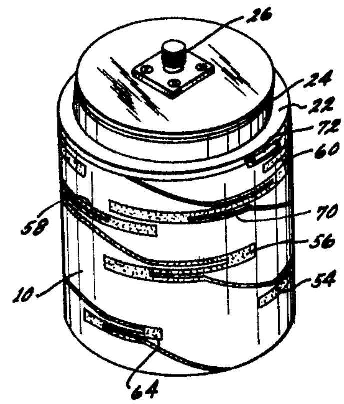

Fig. 2

Fig. 3

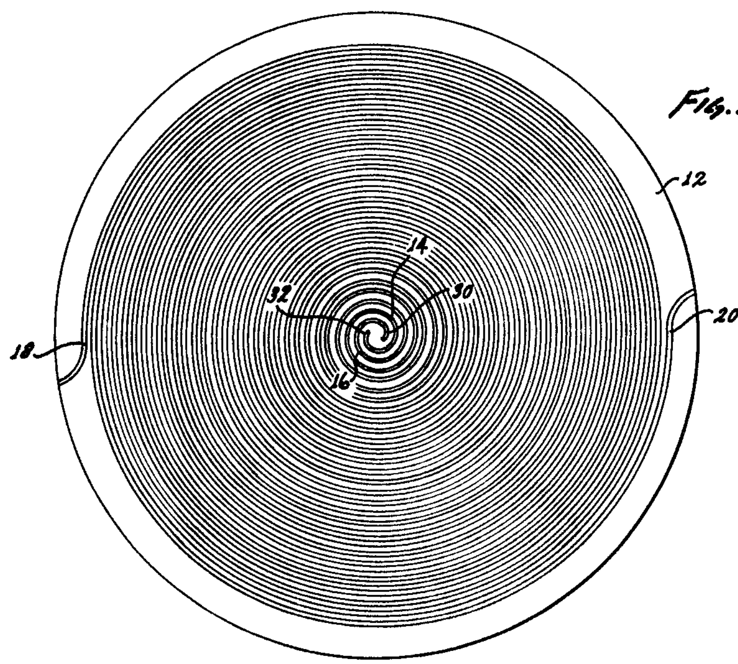

Fig.4

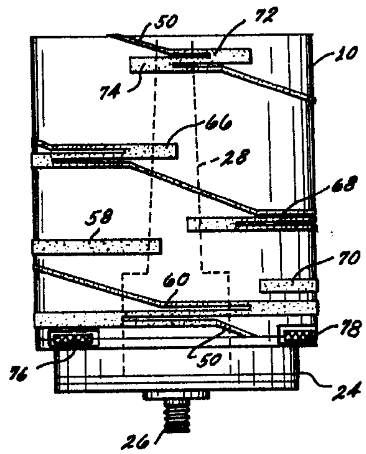
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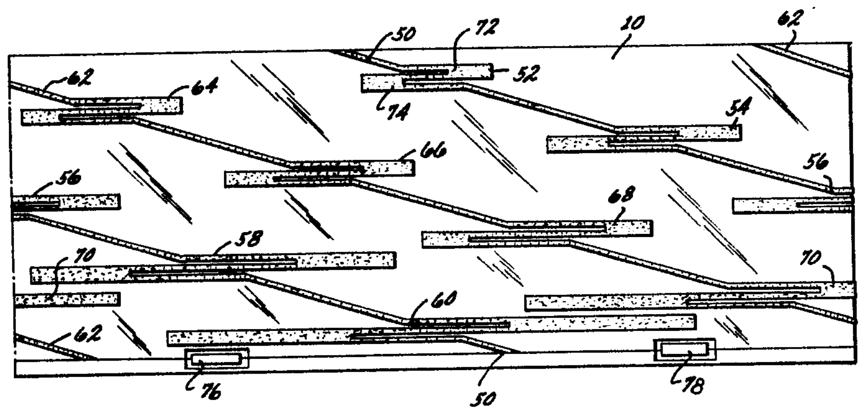
Fig.5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