United States Patent

Corzine et al.

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[54] **DIRECTION FINDING ANTENNA SYSTEM**

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy**

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[52] **U.S. Cl.** ....**343/113 R,** 343/895

[51] **Int. Cl.** **G01s 3/04**

[58] **Field of Search**..............................343/113, 895

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[57] **ABSTRACT**

A missile-mounted antenna array includes a pair of concentric spaced spiral antennas to provide information as to angle and direction of displacement off the boresight axis of an external radiation source.

10 Claims, 9 Drawing Figures

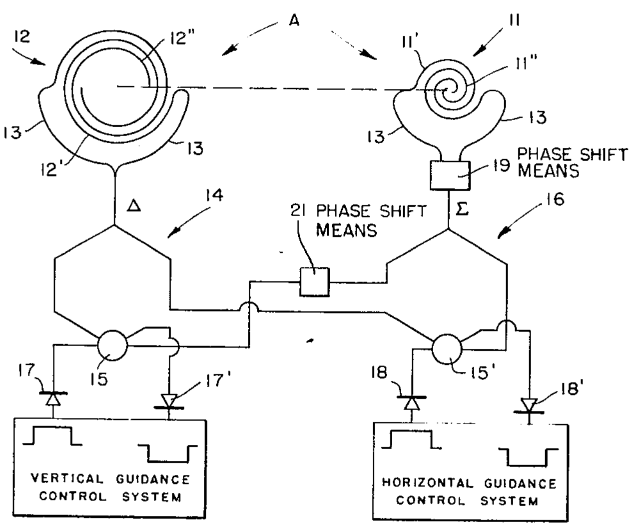
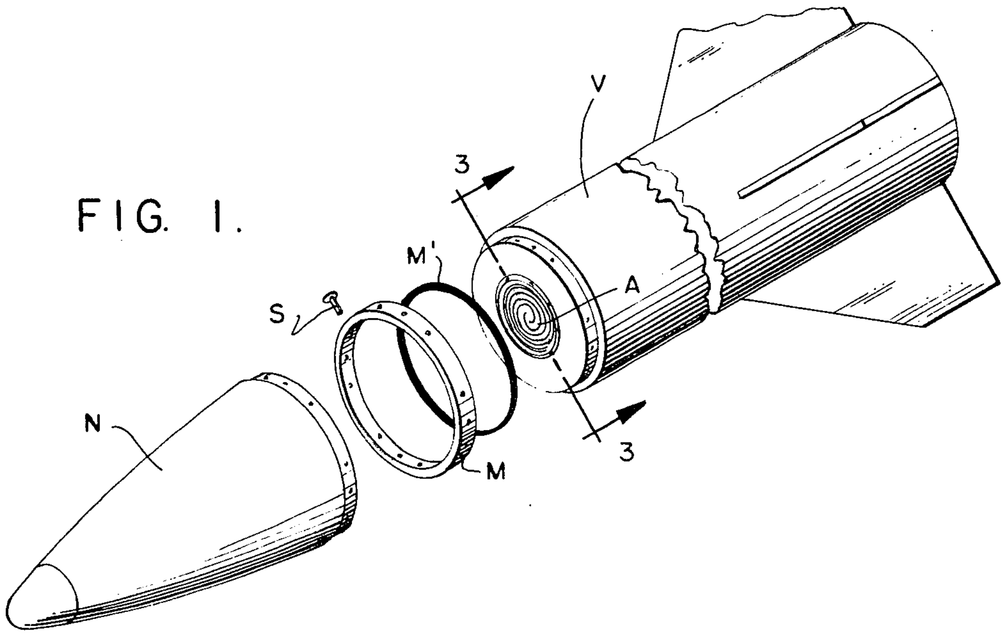


FIG. 1.



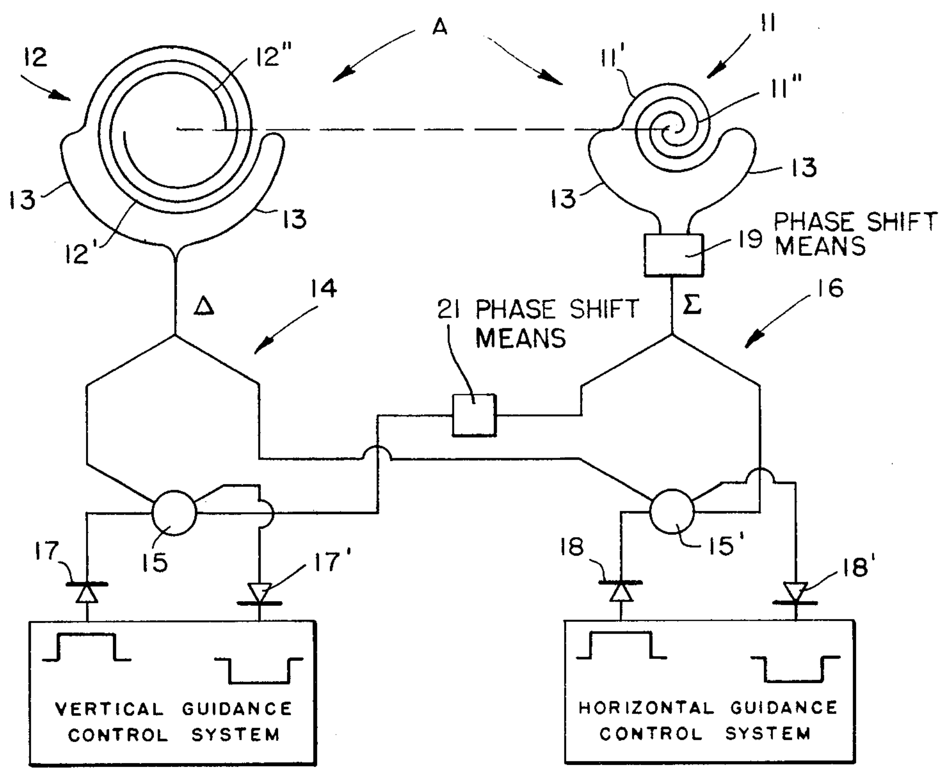


FIG. 2.

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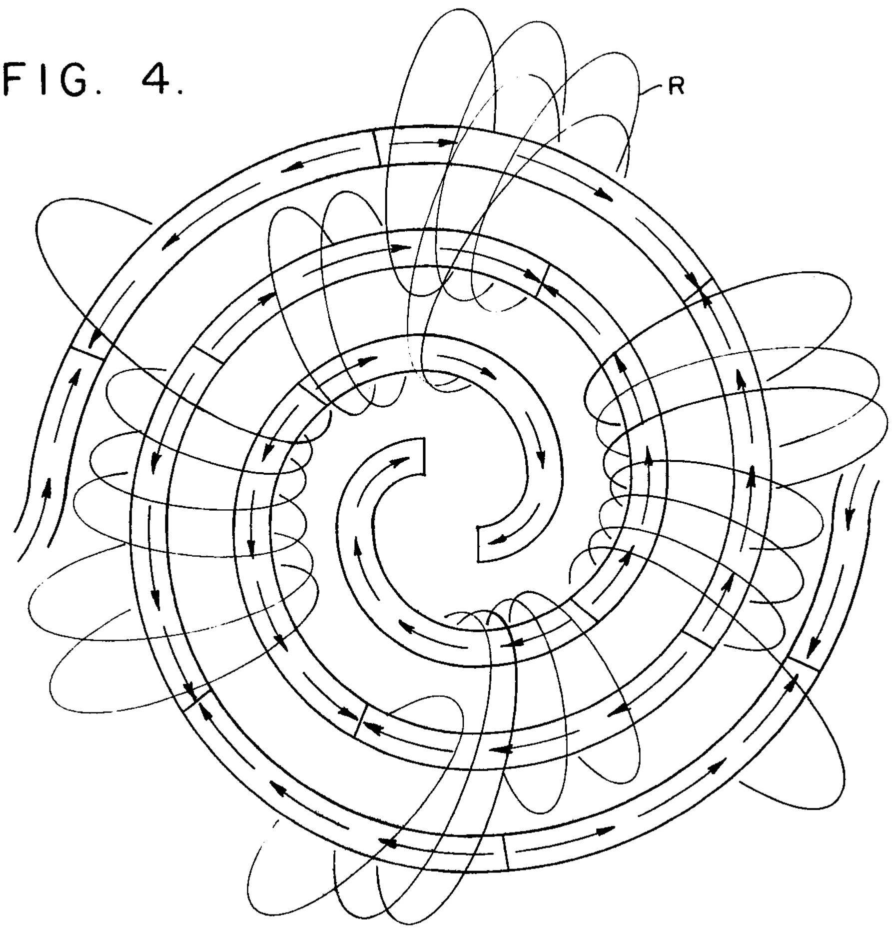
FIG. 4.



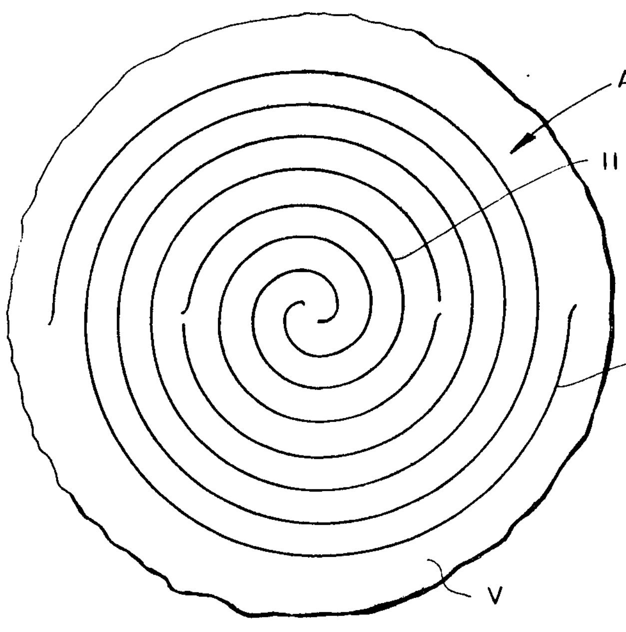


FIG. 3.

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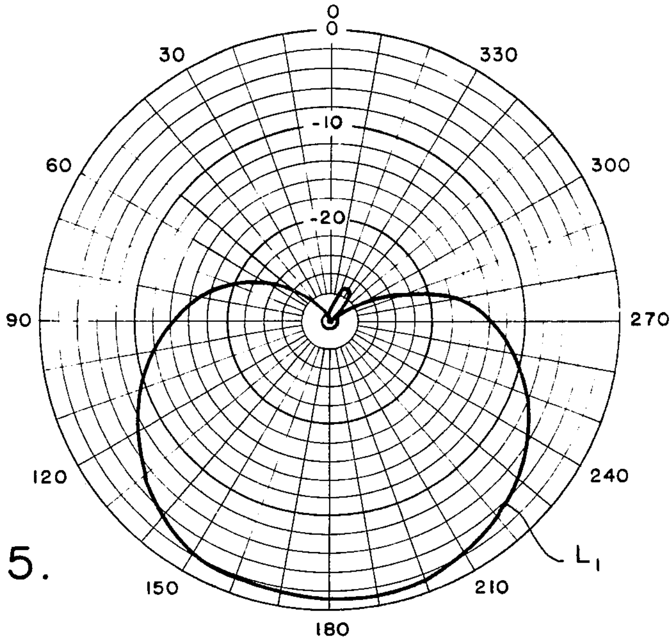

FIG. 5.

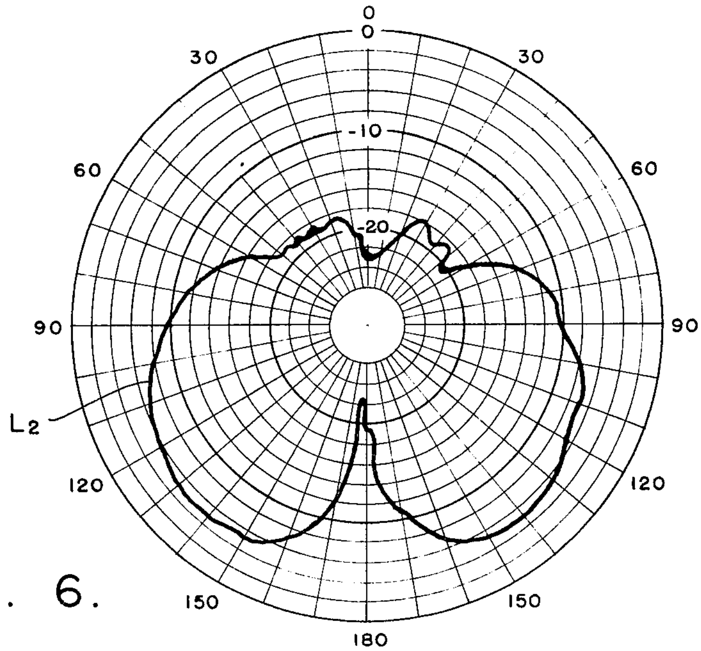

FIG. 6.

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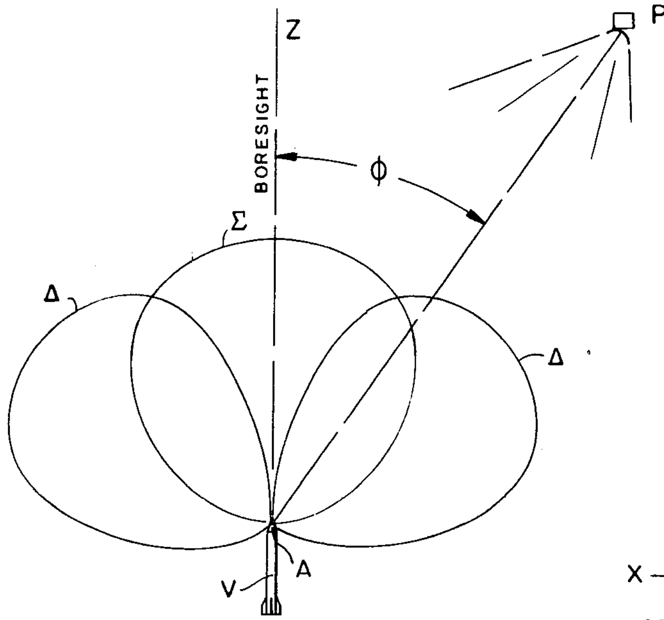


FIG. 7.

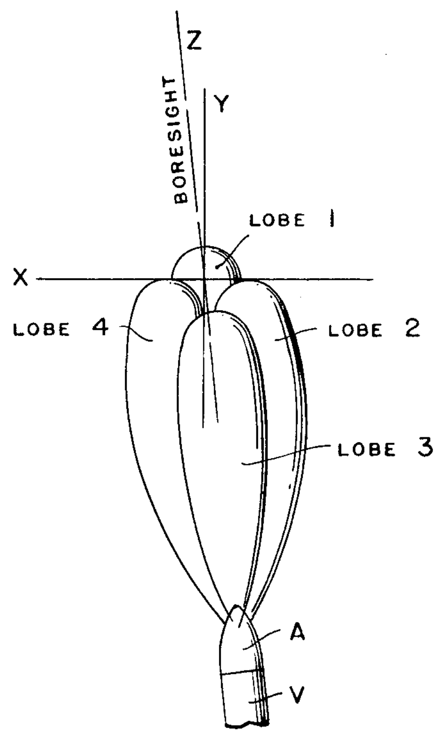
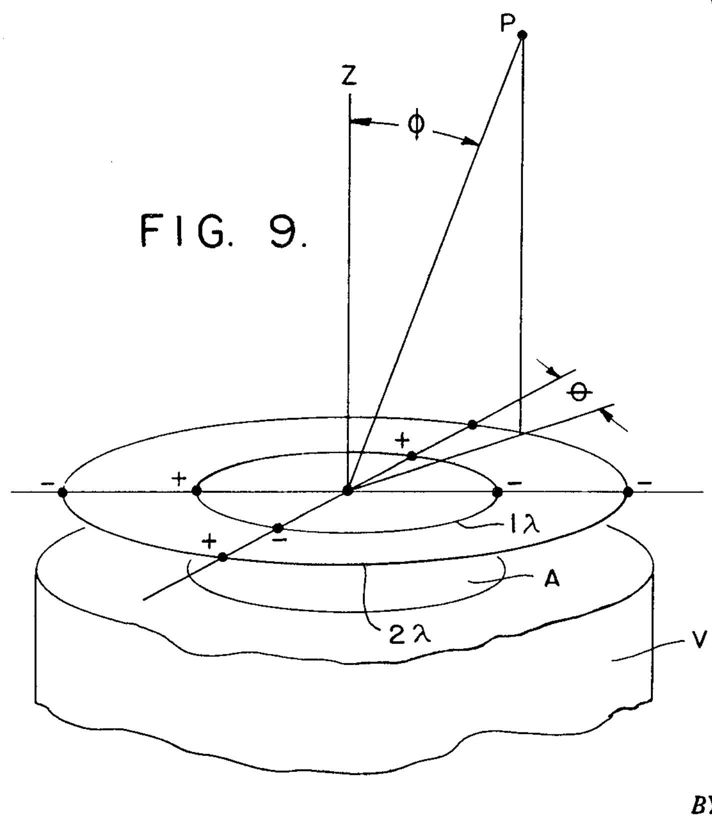


FIG. 8.

FIG. 9.



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DIRECTION FINDING ANTENNA SYSTEM

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates generally to an antenna system, and more particularly to a spiraled antenna array utilized for passive missile guidance.

In the field of antenna design, there has long been an awareness of certain basic disadvantages which limit the use and reduce the efficiency of known arrays in instances where it is necessary to obtain directional information with regard to a given radiation source. Among the disadvantages present in the known arrays are bandwidth limitations, imposed through a given array's element spacing, antenna gain, antenna beam width, design of its feed structure and associated RF (radio frequency) components, as well as its intrinsic complexity, size and weight limitations presently common in antenna design.

Among the many uses made of passive radar systems, the utilization thereof within "guided missiles" imposes some of the more critical limitations with respect to the aforementioned disadvantages. These systems are currently employed to detect, directionally locate and provide navigational information regarding electromagnetic radiation sources in order that given air-to-surface anti-radiation missiles may be caused to "home" on a source and impact within a miss distance compatible with a given "kill radius" of the missile's warhead.

In order for a missile, of the anti-radiation type, to function in a reliable manner, it is necessary that the missile's guidance system be capable of operating over a wide RF bandwidth and a wide range of pulse-repetition frequencies.

However, the physical size of the antenna arrays utilized in present systems limit their use against electromagnetic sources. The physical size of a given antenna array must be compatible with intended purposes of the missile in which the antenna is to be mounted. Therefore, the frequency bandwidth over which the antenna will operate in a reliable fashion is necessarily limited through the missile's design parameters, and, as presently designed, antenna arrays utilized in anti-radiation missile guidance systems respond to radiation over a bandwidth of approximately 600 megacycles in the "S band" frequency spectrum.

Some of the many guidance problems may be overcome by causing a given anti-radiation missile to be fired ballistically as a rocket into a field of radiation with guidance control being subsequently imposed only for the terminal portion of the missile's trajectory to the radiation source under influence of the radiation field. The subsequent guidance control must, therefore, be imposed through a simple, economical system capable of providing accurate direction information to the missile's guidance system which, accordingly, must be capable of being mounted within the missile's leading or forward portion.

Therefore, it is the purpose of this invention to provide a simple, dependable, lightweight antenna array for a passive radar system utilized for detecting and locating sources of electromagnetic radiation over at least a twenty percent bandwidth for seeking and destroying electromagnetic radiation sources.

It is an object of the present invention to provide a simple, lightweight antenna array to be utilized with passive radar systems, for locating and tracking sources of electromagnetic radiations.

Another object is to provide a simple directional antenna array capable of functioning at frequencies extending over a broad bandwidth.

A further object is to provide a missile-mounted antenna array and method for locating a source of electromagnetic radiations in missile guidance operations.

Still another object is to provide a single missile mounted antenna array which provides direction intelligence with regard to an electro-magnetic radiation source's displacement off missile boresight.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

FIG. **1** is a schematic view of a missile having mounted at it's forward portion a dual-spiral antenna array of the present invention;

FIG. **2** is a diagrammatic view, in exploded form, showing the spirals of the array of FIG. **1**;

FIG. **3** is an elevation, illustrating an assembled, concentrically mounted two-arm spiral antenna array, on an enlarged scale, as utilized by the present invention;

FIG. **4** is a schematic view illustrating the operation of a single two-arm spiral antenna;

FIGS. **5** and **6** are schematic views illustrating radiation lobes utilized by two-arm spiral antenna of the present invention;

FIG. **7** is a schematic view depicting utilization of the lobes shown in FIGS. **5** and **6**;

FIG. **8** is a schematic plan view illustrating a lobe pattern effected by the present antenna system; and

FIG. **9** is a diagrammatic view illustrating an operation of the present invention.

Referring more specifically to the drawings wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. **1** a missile or vehicle V having a generally flat, spiraled antenna array assembly A formed of a pair of concentrically mounted antenna array components **11** and **12**, FIG. **2**, arranged in a plane transverse to the longitudinal axis of the missile V and facing the intended direction of travel beneath a radome N. The radome N is of a suitable design and, as illustrated, serves as nose cone for the missile V. Means are provided for securing the radome N to the missile V in any suitable manner, for example, a conventional ring assembly M having a sealing member M', may be utilized for this purpose. The various assemblies and components are secured in any suitable fashion, for example, screws S serve quite satisfactorily in instances where the missile will not be subjected to intensive vibration over extended periods.

Turning now to FIGS. **2** and **3**, the antenna array A is diagrammatically shown with its normal concentrically mounted spiral components **11** and **12** being separated from concentricity for purpose of illustration only, in order to provide a clearer description and understanding of the operation thereof. It is to be particularly noted that in order for the array A to function as an operative device, it is necessary that the spiraled component 11 be concentrically mounted with respect to the spiraled component 12, and in a common plane therewith.

The components 11 and 12 are formed as flat Archimedian spirals, and wound in a common direction with each component having a pair of dipole-like conductors designated by reference numerals 11', 11'', and 12', 12''. The conductors of each pair are of equal length and are wound to form a spiral geometrically defined as: $R = a\theta$; where R is a radius vector from the origin of a curve, formed by the spiral, to a selected point on the curve; $a = a$ value of preselected constant defining the rate of expansion of the conductor; and $\theta =$ the angle of rotation as measured in radians. A spiral of this configuration provides a linear rate of expansion for each of the conductors with the size thereof being maintained constant. The conductors of each pair are connected at their outer ends to a RF (radio frequency) receiving system, through strip transmission line leads 13, and are unidirectionally wound so that the conductors of each component are adjacent to and insulated from each other and terminate near the center of the spiral with the ends thereof being oppositely disposed and insulated from each other.

A theoretical basis for operation of a spiral antenna is the "current band" theory, which postulates that radiation R, FIG. 4, occurs from a radiation band on the spiral surface in an area where the currents in adjacent conductors are most nearly in phase. If the arms, or conductors, of a spiral antenna components are fed so that the current applied to each of the conductors is 180° out of phase, with respect to the other, the current in the conductors will return to an in-phase condition, due to the geometry of the spiraled conductors, and a first radiation band will occur generally where the circumference of the band is equal to one wavelength at an operating frequency.

However, it is to be noted that where an in-phase current is introduced into the opposite conductors of a two-arm spiral antenna, a radiation band will occur at a circumference equal to approximately two wavelengths at an operating frequency, since the currents in the two antenna conductors remain in phase for only an insignificant number of turns thus requiring that the current being fed into both conductors progress through a sufficient number of turns in order for the currents to return to an in-phase condition. These radiation phenomena are known and are more fully described in an article entitled "Design Techniques for a Light Weight High Power Spiral Antenna", by J. P. Jones, P. E. Taylor, and C. W. Morrow, as found at page 107, Part 1, of the 1960 IRE WESCON Convention Record.

It suffices, however, to understand that a band of radiations R will occur for the inner spiraled component 11 at a mean circumference of one λ, or wavelength, at a given frequency of operation, and a radiation band for the outer spiral component 12 will occur at a mean circumference of two λ, or wavelengths, at the same frequency. Consequently, as the frequency of operation is varied, the physical size of the mean circumference of the bands will be caused to vary accordingly. However, it is to be particularly noted that the electrical circumference, in terms of wavelengths, remains constant thus imposing a physical limitation on the bandwidth of the array of 2:1.

In practice, the spiral component 11 is formed with a circumference which is at least slightly greater than a length of a single wavelength of a lowermost frequency for which the antenna array A is designed to operate. The component 12 is formed with a circumference which is at least slightly greater than a length of the sum of two wavelengths of the operating frequency, but with the conductors thereof terminating near the center of the spiral in a manner which provides a vacant, or void, space of a sufficient dimension so as to permit a mounting of the spiraled component 11 within the confines thereof and in a common plane therewith. A suitable dielectric material may be used to mount the components, and where desired, the array may be formed by techniques utilized in "printed circuit" design and construction.

Assume, for purposes of illustration, that each of the spiraled components 11 and 12 of the array A are being caused to function as a radiating antenna. It will be understood, therefore, that when the conductors of the component 11 are fed 180° out of phase, axial mode radiation will occur causing a maximum radiation to occur in a single lobe pattern in a plane perpendicular to the plane of the radiating array, see lobe L_1 of FIG. 5, and when the conductors of the component 12 are fed in phase, a normal mode radiation will be effected causing a maximum radiation to occur in a forward looking doughnut pattern, as generally as indicated by lobe L_2, FIG. 6. Therefore, and since it is well known that a radiating antenna may be caused to function as a receiving antenna exhibiting receiving characteristics similar to its radiating characteristics, it is to be understood that when the components or spirals 11 and 12 of the antenna array A are concentrically disposed in a common plane, they may be caused to receive in a pattern of overlapping radiation lobes, see FIG. 7, by treating the incoming signals with a proper signal processing circuit.

Turning again to FIG. 2, the outer spiraled component 12 has its conductor output leads 13 connected to a difference circuit, generally designated by the reference numeral 14, which provides input signals at hybrid ring junctions 15 and 15'. The component radiates, or here receives, a two wavelength circumference mode Δ, corresponding to the lobe pattern L_2, as shown in FIG. 6. The inner spiraled component 11 is connected to a sum circuit, generally designated by reference numeral 16, which also provides input signals at the hybrid ring junctions 15 and 15' in order for these junctions to function as sum and difference units to compare the input signals and provide output signals to video detectors 17 and 17' of a vertical control, or servo, mechanism to provide for missile guidance in a vertical direction, and detectors 18 and 18' of a horizontal control or servo mechanism to provide for horizontal guidance.

A broadband balun or constant 180° phase shift means 19 of known design, is coupled between the output leads 13 of the spiral component 11 in order that there be established a 180° phase difference between the conductors 11' and 11'' of the spiral component 11 so that the antenna component 11 radiates, or as here receives, a one wavelength circumference mode Σ, depicted in FIG. 7, and corresponding to lobe L_1, FIG. 5. At this juncture it is well to note that the lag in the phase of the current of the inner spiraled component **11** is indicative of the relative direction of a point source P of radiation, and will be detected in lobes 180° apart, for example, lobes LOBE **2** and LOBE **4**, FIG. **8**, when the phase of the current in the component **11** is compared with the phase of the current in the component **12**. A broadband constant 90° phase shift means **21** is provided in series between the 180° phase shift means **19** and the hybrid ring **15** and serves to shift the phase of the output of the phase shift means **19** in order to establish a four-lobe pattern by, in effect, causing lobes LOBE **1** and LOBE **3** to be rotated 90° from lobes LOBE **2** and LOBE **4**, as illustrated in FIG. **8**. The technique utilized in establishing this four-lobe pattern may be more clearly understood when it is recalled that the antenna array A is made up of two spiraled components **11** and **12**, one being concentrically mounted within the other. Therefore, as radiation signals are emitted from a source P, positioned at an angle of error ϕ of boresight, a current will be induced in the inner spiraled component **11** which will lag the current in the outer spiraled component **12** by an amount dictated by the magnitude of the angle θ. Since the currents in the components **11** and **12** are continuously reversing direction, a lag in the phase of the inner spiraled component relative to the outer spiraled component may be detected. Thus it is to be understood that, in effect, two radiation signal detecting lobes LOBE **2** and LOBE **4** are established. However, for present purposes the phase established two lobe pattern does not suffice, therefore, it has been found that by inserting a constant 90° phase shift means **21** within the antenna input circuit, of the component **11**, to shift the phase of the components input 90°, the lag of the current induced in the inner spiral may be detected in all four quadrants, or as here, in four lobes, LOBES **1**–**4**.

The phase and amplitudes of currents excited on the spiral elements **11** and **12** are compared by the circuitry consisting of the components **14**, **15**, **15'**, **16** and **21**. The difference in phase of the current from the spiraled element **11** and the current from spiraled element **12**, is proportional to the angle θ, to provide direction, while the difference in amplitude of these currents is proportional to the magnitude of angle ϕ off boresight, as depicted in FIG. **8**. In essence, circuit components **15**, **15'**, **19** and **21**, of circuits **14** and **16**, cause the $\Sigma - \Delta$ patterns, shown in FIG. **7** to be transformed, at the outputs **17**, **17'** and **18**, **18'**, to a four-lobe pattern, FIG. **8**.

Therefore, it is understood that when a point source of radiation P is located along the boresight axis Z of missile's antenna array A, an output signal of maximum amplitude occurs at the output of the spiral component **11**, while the signal at the output of the antenna component **12** is insignificant, since the radiation source is at the null of the lobe pattern Δ and at the center of the pattern Σ. However, as the source P moves to one side or the other of the boresight axis Z, to increase angle ϕ, FIG. **9**, the amplitude of the output of the component **12** increases, while the amplitude of the component **11** decreases. Therefor, a difference signal may be obtained at outputs **17**, **17'** and **18**, **18'** to provide an indication of the angle ϕ, which may be defined in degrees, and utilized by an appropriate missile guidance control unit, which forms no part of the present invention, for changing direction of the missile's flight to the extent necessary for repositioning the source P along the boresight axis Z.

In operation, a missile V, with its associated signal processing system, is launched into a field of radiation being emitted from a target source or point P. The missile's receiver system processes antenna received radiation for guidance purposes so as to direct the missile toward the point P. The conductor of the inner spiral **11** is caused to receive radiation in a single lobed pattern directed along the missile's boresight axis Z and perpendicular to the array A. The outer spiral **12** is caused to receive radiation in a pattern comprising a forward looking lobe with a null at boresight. The amplitudes of the signals, obtained through the separate components of the array A, indicate the angle of displacement ϕ of the source P of radiation from the missile's boresight axis Z, while a phase comparison between the signals of the inner spiral component **11**, as processed, and the phase of the outer spiral **12** are provided as indicative of the direction of displacement θ of the radiation source P with respect to horizon and azimuth, as indicated by an "X" and "Y" axis, FIGS. **8** and **9**. These signals are then directed to pairs of video detectors **17**, **17'** and **18**, **18'** to provide directional input signals to the missile's vertical and horizontal control guidance units so as to provide missile guidance or "homing on" the radiation point source P.

Therefore, in accordance with the above it is to be understood that there has been provided an antenna array comprising a pair of spiral components being concentrically mounted in a common plane, by means of a suitable dielectric, for mounting within an anti-radar missile to receive radiation from a radiation source and provide directional guidance intelligence to the missile's guidance system so that the missile may "-home in" on the source.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A directional broadbandwidth antenna array comprising:

- a first spiral-wound antenna component formed of a pair of adjacently disposed spiraled dipole-like conductors;
- a second flat spiral-wound antenna component formed of a pair of adjacently disposed spiraled dipole-like conductors; and
- means concentrically mounting said first and said second antenna components within a common plane with said first antenna component surrounded by said second antenna component.

2. The array of claim **1** further characterized in that the circumference of said first component is at least greater than a single wavelength at a desired lowermost operating frequency and the circumference of said second component is at least greater than two wavelengths at said desired lowermost frequency for causing a radiation band to occur at a mean circumference of one wavelength for said first component and a radiation band for said second component to occur at a mean circumference of two wavelengths, thereby providing a pair of separate signals simultaneously generated by said array.

3. The array of claim **2** wherein means are provided so that the spiraled conductors of said first component are caused to provide signals out of phase with respect to each other and the spiraled conductors of said second component are caused to provide signals in phase with respect to each other so that a pair of scanning lobes are thus provided.

4. A passive directional broadbandwidth antenna device comprising in combination:

a first flat spiraled antenna component having a pair of spiraled dipole-like conductors adjacently disposed throughout their lengths and terminating within the component;

a second flat spiraled antenna component having a pair of spiraled dipole-like conductors adjacently disposed throughout their lengths and terminating within the component so as to provide a vacant cavity-like area near the center portion thereof;

means for mounting said first component within said area and concentrically with said second component in a manner so as to dispose the first and second components within a common plane;

means for obtaining output signals at the outer ends of each of said conductors;

signal processing means for shifting the phase of the output signals of said first component; and

means for determining relative direction and angle of displacement of a radiation emitting source with respect to said device by observing and comparing the amplitude and phase of the output signals of said first and second components.

5. A directional broadbandwidth antenna array comprising:

a first spiral-wound antenna component formed of a pair of adjacently disposed spiraled dipole-like conductors;

a second flat spiral-wound antenna component formed of a pair of adjacently disposed spiraled dipole-like conductors;

means concentrically mounting said first and second antenna components in a common plane; and

means for causing each of the spiraled conductors of the first component to provide signals from the outer ends thereof out of phase with respect to each other and for causing the spiraled conductors of said second component to provide signals from the outer ends thereof in phase with each other so as to provide separate scanning signals simultaneously received by said array.

6. A directional broadbandwidth antenna array comprising:

a first spiral-wound antenna component formed of a pair of adjacently disposed spiraled dipole-like conductors spiraling out from a center point to a predetermined diameter;

a second spiral-wound antenna component formed of a pair of adjacently disposed spiraled dipole-like conductors of greater diameter than said predetermined diameter and encompassing said first antenna component; and

means concentrically mounting said components in a common plane.

7. The array of claim **6** wherein:

said predetermined diameter is such as to provide said first component with a circumference which is at least greater than a single wavelength at a desired operating frequency; and

said greater diameter is such as to provide said second component with a circumference which is at least greater than two wavelengths at said desired operating frequency.

8. The array of claim **7**, further characterized in having means for causing the conductors of the first component to provide signals out of phase with each other and for causing the conductors of the second component to provide signals in phase with each other.

9. A directional broadbandwidth antenna array comprising:

a first spiral-wound antenna component including a pair of adjacently disposed spiraled dipole-like conductors having inner ends adjacent a center point and outer ends oppositely disposed at a predetermined diameter such that the circumference of the first component is at least greater than one wavelength at a desired lowermost operating frequency;

a second spiral-wound antenna component including a pair of adjacently disposed spiraled dipole-like conductors having inner ends adjacent the outer ends of the first component and outer ends oppositely disposed at a greater diameter such that the circumference of the second component is at least greater than two wavelengths at said desired lowermost operating frequency; and

means mounting said first and second antenna components concentrically in a plane.

10. The array of claim **9**, further having means for causing each of the conductors of the first antenna component to provide signals from the outer ends thereof out of phase with each other and for causing each of the conductors of the second antenna component to provide signals from the outer ends thereof in phase with each other.

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