United States Patent [19]

Munson

[11] **3,769,622**

[45] **Oct. 30, 1973**

[54] **ANTENNA WITH ELECTRICALLY LONG SUPPORT**

[75] Inventor: **Robert E. Munson,** Boulder, Colo.

[73] Assignee: **Ball Brothers Research Corporation,** Boulder, Colo.

[22] Filed: **Sept. 11, 1970**

[21] Appl. No.: **71,552**

[52] **U.S. Cl.** **343/797,** 343/DIG. 2, 343/792, 343/885

[51] **Int. Cl.** **H01q 21/26**

[58] **Field of Search** 343/790, 791, 792, 343/795, 802, 807; 347/791, 792, 801, 802, 828, 829, 841, 846

[56] **References Cited**

UNITED STATES PATENTS

2,286,179	6/1942	Lindenblad	343/802
2,648,768	8/1953	Woodward	343/792
2,683,808	7/1954	Shumaker	343/802
2,724,052	11/1955	Boyer	343/791
2,748,387	5/1956	Klancnik	343/802
3,139,620	6/1964	Leidy et al.	343/792
3,196,443	7/1965	Martin	343/797

Primary Examiner—Eli Lieberman
Attorney—Gilbert E. Alberding

[57] **ABSTRACT**

An antenna for providing an omnidirectional pattern in an environment which includes conductive members which are long relative to a wavelength of the electromagnetic energy for which the antenna is designed, including means for utilizing relatively short portions of selected ones of such long members as a part of the antenna structure, and preventing propagation of such electromagnetic energy along the remaining portion of each of such selected members.

11 Claims, 6 Drawing Figures

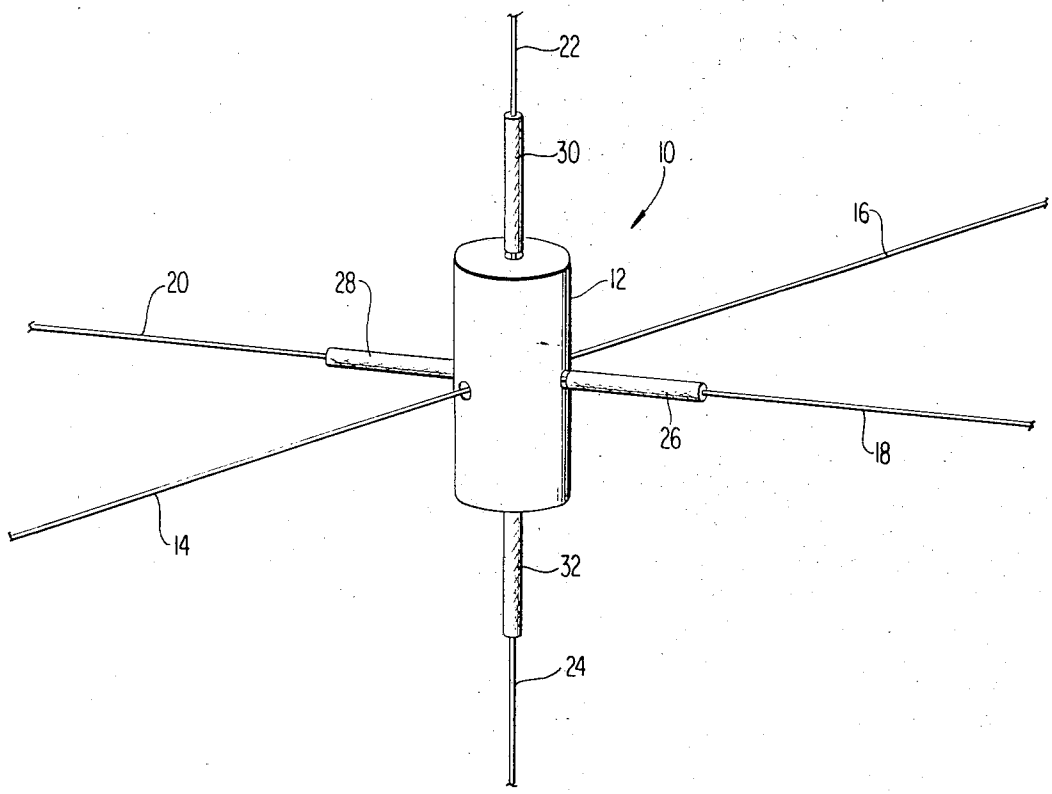


FIG. 1

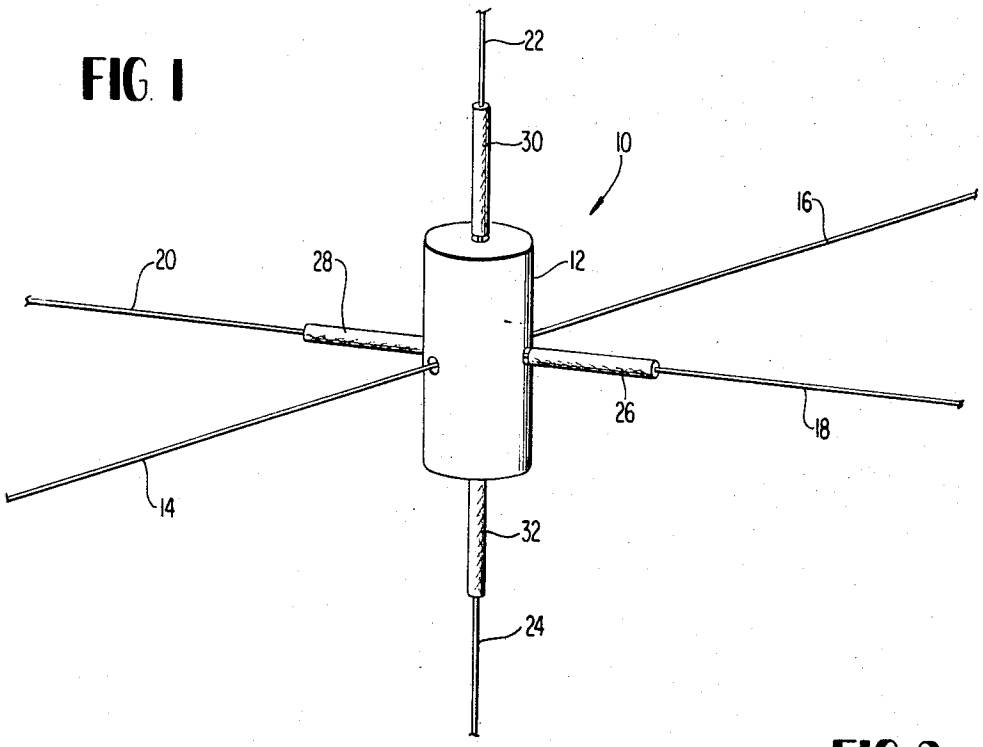
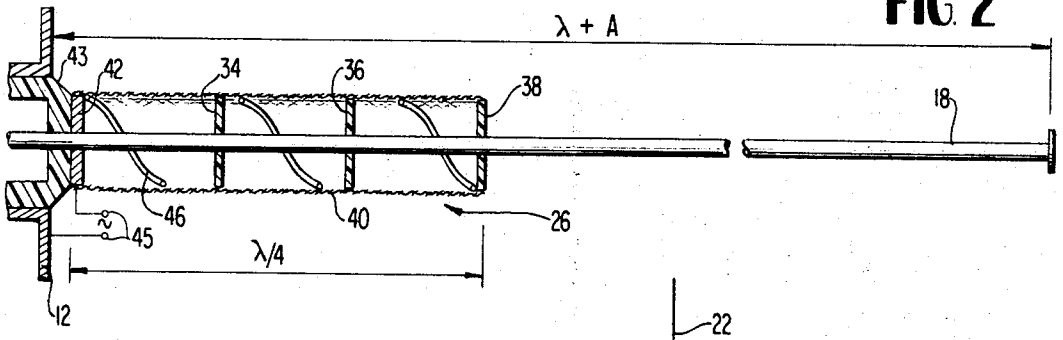


FIG. 2



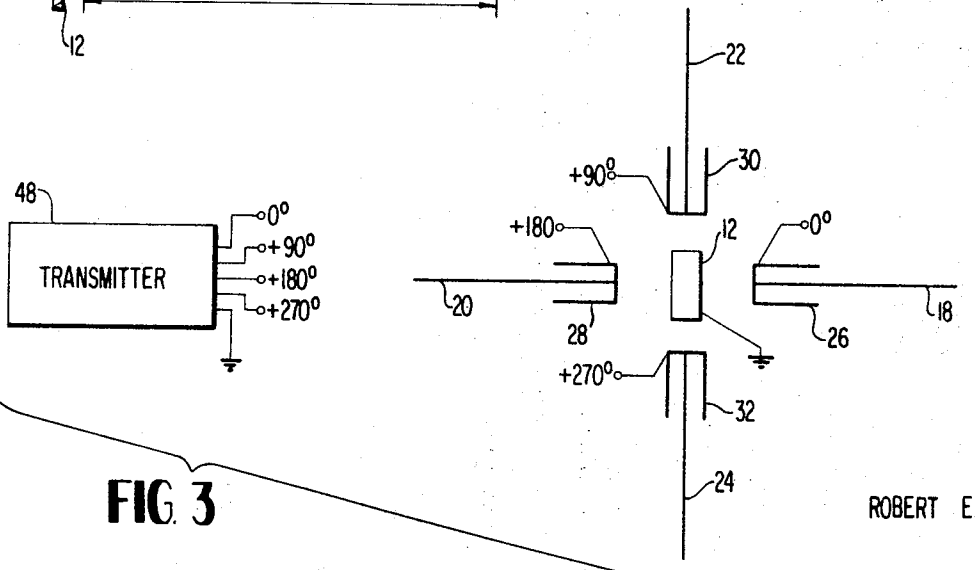


FIG. 3

INVENTOR
ROBERT E. MUNSON

BY Robert E. Harris

ATTORNEY

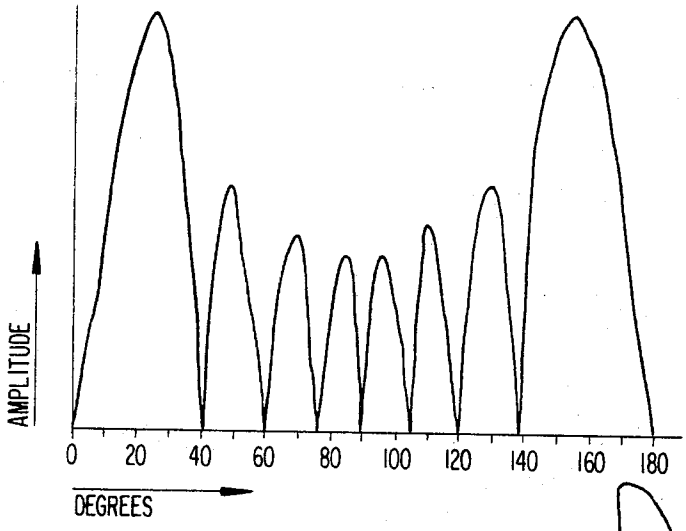


FIG. 4

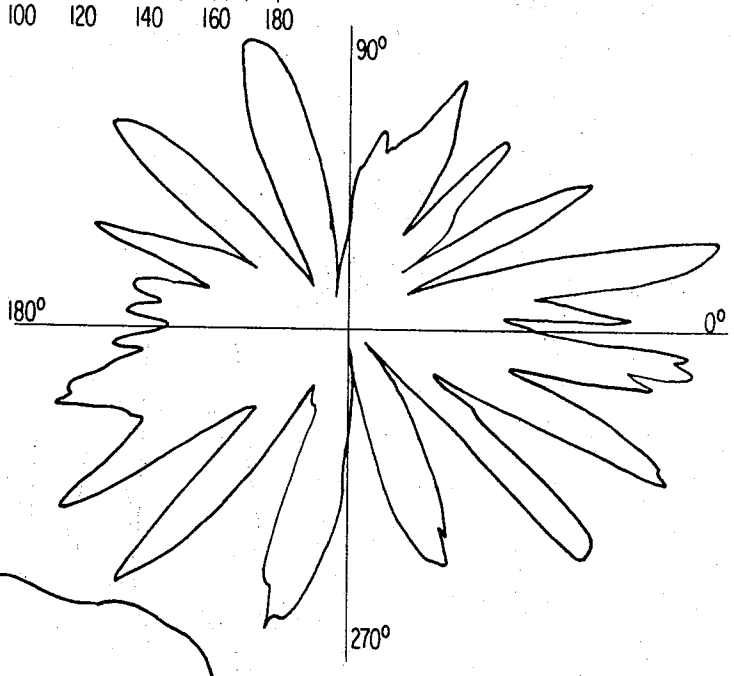


FIG. 5

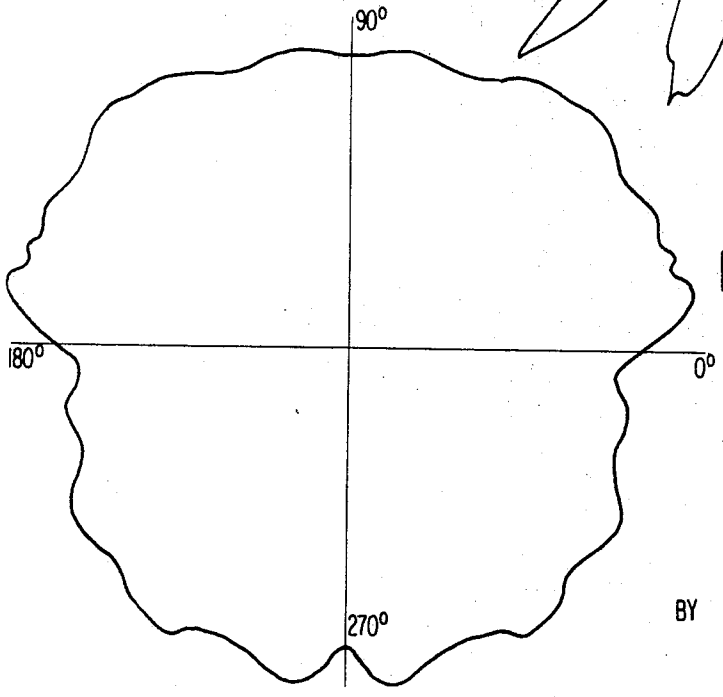


FIG. 6

INVENTOR
ROBERT E. MUNSON

BY Robert E. Harris

ATTORNEY

ANTENNA WITH ELECTRICALLY LONG SUPPORT

This invention pertains generally to antennas, and more particularly to an antenna suitable for use in an environment which includes elongate conductive members which are long compared to a wavelength of the energy spectrum for which the antenna is designed.

More specifically, this invention pertains to antennas employed in applications or practical uses in which the antenna is only one of a plurality of, in some instances, rather sophisticated devices which are, of necessity, packaged in close proximity or limited quarters for simultaneous operation. For example, in the relatively new but rapidly expanding art of spacecraft design, it is often required that microwave communication or telemetry antennas be physically mounted on and mechanically compatible with elongate booms or the like which deploy other electronic or even unrelated devices into suitable position once a spacecraft has attained a given altitude and orbit configuration.

The fact that a radio frequency antenna is required to perform in an environment filled with non-related and often incompatible components of various sorts is a rather demanding situation. Especially where an antenna or antenna array forms a part of a spacecraft or other assembly which necessarily includes electrically conductive booms or other appendages of a length greater than the operating wavelength of the antenna, there exists the problem of obtaining satisfactory operation of the radio frequency equipment in spite of antenna pattern deterioration produced by such appendages, since the booms may be excited by the transmitting antenna and reradiate with multilobe and multinull characteristics.

Where a given antenna pattern is desired, it is a relatively straightforward task, in the absence of interfering structures, to design an appropriate antenna to produce the required configuration. For example, a "figure eight" pattern may be produced by the utilization of a half-wave dipole antenna, while a suitable combination of such dipoles or a turnstile array may be employed to effect an omnidirectional pattern. Where, however, the immediate vicinity of the antenna includes conductive members of significant electrical length, the desired radiation pattern can be seriously degraded or even rendered useless.

This problem is particularly acute in the design of antennas for use on spacecraft. For example, it is not an uncommon requirement that a radio frequency communications or telemetry antenna be characterized by an omnidirectional pattern, though the antenna structure must form a part of, or be closely adjacent to, long conductive boom members which form supporting structures for other components. While highly directive antennas may be designed for use in such applications, thereby obviating the undesirable effects of such long booms in establishing an effective communication link between such a spacecraft and, for example, a ground station, there then arises the need to control the orientation or attitude of the spacecraft relative to the earth or other station, so that the directive pattern is properly aimed. In a spacecraft or the like not otherwise designed for controlled attitude, the requirement for such control constitutes an unnecessary burden, and even in a spacecraft which includes means for attitude control for performing some other function, it is not unlikely

that the orientation required by such other function be different from that required by the aforementioned directive antenna.

It is accordingly a primary object of the present invention to provide an antenna which is capable of producing a desired radiation pattern in spite of the presence of interfering structures.

Another object of the present invention is to provide an antenna characterized by a radiation pattern of a desired configuration and utilizing as a part of the antenna a structure which, in the absence of the design of the present invention, would undesirably distort such pattern.

In accordance with a preferred embodiment of the present invention, these and other objects are achieved by means of an antenna which includes a plurality of radiating means relatively positioned in a given array, each of said radiating means being of a length at least equal to one-quarter of the wavelength for which the antenna is designed, means for applying electrical energy to such radiating means to effect radiation of electromagnetic energy therefrom, and means operatively associated with each of such radiating means which is of a length in excess of such one-quarter wavelength for limiting the radiation from each such electrically longer radiating means to a portion thereof equal to such one-quarter wavelength.

With the above considerations and objects in mind, the invention itself will now be described in connection with a preferred embodiment thereof, given by way of example and not of limitation, and with reference to the accompanying drawings, in which:

FIG. 1 is a perspective view of a preferred embodiment of the present invention as applied to its use in a spacecraft,

FIG. 2 is a sectional view of one of the radiating elements shown in FIG. 1, including a schematic representation of a preferred means for applying an electrical signal thereto,

FIG. 3 is a schematic electrical diagram of the manner of excitation of the several elements in FIG. 1,

FIG. 4 is a representation of the radiation pattern of a typical electrically long linear radiator,

FIG. 5 is a representation of the radiation pattern of a typical antenna array similar to that shown in FIG. 1, but without utilization of the concept of the present invention, and

FIG. 6 is a representation of the radiation pattern of the aforementioned array in accordance with the present invention.

Referring now particularly to FIG. 1, the antenna of the present invention is shown in connection with a spacecraft indicated generally at **10** and including a central body **12** of generally cylindrical shape having a plurality of mutually orthogonal elongate members or booms **14, 16, 18, 20, 22** and **24** symmetrically disposed with respect to the main body **12.** It will be understood by those skilled in the art that these several boom members may be utilized for a number of different purposes; they may form relatively low-frequency antennas, or may serve only as a mechanical support. For example, they may be employed as a means for deploying and supporting a plurality of equipments and components (not shown) which form a part of the spacecraft assembly, but which are designed to be disposed in spaced relationship with respect to the body of the spacecraft at a distance corresponding to the

length of the boom members. That is to say, in order to perform its assigned tasks in space, the spacecraft **10** necessarily includes the plurality of elongate conductive booms **14** through **24**, thus creating an undesirable or adverse environment for the inclusion in the spacecraft assembly of a suitable antenna or antennas, as previously discussed, since electromagnetic energy radiated by an antenna forming a part of such an assembly may excite one or more of the several booms, which, in turn, will reradiate the incident signal, but in a multilobe and multinull manner which plays havoc with the intended radiation pattern of the antenna. It is this problem to which, basically, the present invention is addressed.

In carrying out the present invention in its preferred form, a plurality of cylindrical conductive members **26, 28, 30** and **32** are employed, each being disposed in coaxial relationship with a respective one of the aforementioned plurality of conductive boom members. As will be further described in connection with FIGS. **2** and **3**, the several cylindrical conductive members are electrically insulated from their respective booms except at the ends adjacent the spacecraft body **12**, where the cylindrical members are each shorted to their respective booms. Further, means are employed to apply between each cylindrical member (and its respective boom) and the spacecraft body **12** an electrical signal corresponding to the electromagnetic energy to be radiated. Thus, each cylindrical member and its respective boom act as a coaxial line throughout their common length for propagating the electromagnetic energy, and the physical length of each of the cylindrical members **26, 28, 30** and **32** is equal to one quarter of the wavelength of that energy. As a result, each of the coaxial assemblies acts not only as a quarter-wave monopole radiating element, but also as a quarter-wave choke, in view of the open outer end of each coaxial assembly, thus preventing the propagation of the electromagnetic energy out along each boom past the end of the coaxial portion thereof.

Before leaving the description of the preferred embodiment as shown in FIG. **1**, it should be noted that cylindrical members **26** and **28** are disposed in opposed aligned relationship, forming between them a dipole, as is the case with cylindrical members **30** and **32**, assuming in each case a suitable means of excitation whereby the opposed members are fed in phase opposition, as will further be described. Also, the four cylindrical members taken together, in view of their mutually orthogonal relationship, are adapted to the formation of a turnstile array, again assuming excitation of the respective elements in the proper phase relationship, as will be further described.

Referring now to FIG. **2**, one of the mutually orthogonal elements of FIG. **1** is shown in greater detail. The cylindrical conductive element **26** is supported in coaxial relationship with the boom **18** by a plurality of insulating spacer members **34, 36** and **38**, each of which plays a part in supporting the conductive material **40** in proper alignment with respect to the boom **18**. The end of cylindrical member **26** adjacent the spacecraft body **12** is shorted to the boom **18** by means of a conductive spacer **42**.

The electrical length of the cylindrical member **26** from conductive or shorting spacer **42** to insulating spacer **38** is one quarter of the wavelength of the energy to be radiated, whereas the total length of boom **18** is long compared to such wavelength, as is indicated by the lengend in FIG. **2**, wherein the letter "A" is employed to indicate an arbitrary additional length over and above the span of one wavelength.

Since it is generally desirable to restrict the size of a spacecraft to the most compact package possible at the time of launching the craft from the earth, with it later being desirable to effect a craft of greater dimensions when orbit is achieved and wind resistance is reduced or eliminated, it has become common to utilize booms and the like which are erectible by one means or another. Accordingly, in the preferred embodiment of the device of the present invention, the conductive material **40** of the cylindrical member **26** is a flexible conductive substance which is adapted to fold upon itself for compact storage. In this connection, the shorting disk or spacer **42** and the insulating spacers **34, 36** and **38** are adapted to slide along the bottom **18**. With the boom **18** retracted into the spacecraft body **12** by suitable retracting and erecting means (not shown) connected with the inner end of boom **18**, the end cap **44** on the boom **18** serves to collapse the cylindrical member **26** upon itself, with the spacers **34, 36, 38** and **42** thus lying adjacent each other. Since the boom **18** and its respective sleeve **26** must be electrically isolated from the spacecraft body **12**, a suitable insulating mount **43** may be employed, providing a sliding fit with the boom **18**. With the boom and sleeve thus insulated from the body of the craft, an electrical signal may be applied between the craft body and the sleeve (or the boom), as indicated schematically by means of terminals **45**. When the boom **18** is extended, a helical spring **46** or other similar resilient device is employed to extend the cylindrical member **26** to its full length, as shown in FIG. **2**. It will be understood that the description thus given as to boom **18** and the cylindrical member **26** thereon serves equally well as a description for the booms **20, 22** and **24**, along with their respective coaxial sleeves.

FIG. **3** shows schematically the manner of energizing the several structures described above. A transmitter means **48** is shown with four separate outputs, at respective phases indicated as 0°, +90°, +180° and +270°. The spacecraft **12** and the several booms **18** through **24** with their respective coaxial quarter-wave sleeves are also shown in FIG. **3**, along with schematic indications of connections to be made to the several sleeves **26, 28, 30** and **32** in order to energize each in a phase 90° away from the phase of energization of a next-adjacent sleeve (as viewed in FIG. **3**). As is well known to those skilled in the art, a turnstile array is generally energized in a manner such that the electrical energy is equally divided between the several radiating elements, with a symmetrical distribution of the phase relationship therebetween; with four radiating elements, the aforementioned quadrature relationship exists. The particular means for achieving this desired energization of the several elements of the antenna of the present invention are not shown, since any of several known means are acceptable. For example, the transmitter output could be split in a ninety-degree hybrid circuit, the two outputs of which are fed to respective opposed pairs of radiating elements by way of transmission lines whose lengths differ by one-half wavelength. Thus, energy arriving at each radiating element is one-half wavelength out of phase with that arriving at the opposed element, and in quadrature with that of each adjacent element.

The operation of the antenna of the present invention has been described in connection with the foregoing description of the apparatus itself, but it may be restated that the basic concept involved is that of energizing the several quarter-wave sleeves in a selected manner in order to achieve a desired radiation pattern, while preventing (by means of the open circuit at the outer end of each coaxial sleeve) corresponding currents in the remaining or outer portion of each boom. The energization is thus limited to the inner quarter-wavelength coaxial segment, each of which approximates a monopole radiator.

FIG. 4 illustrates a representative radiation pattern of an electrically long boom, where, for example, the boom length is approximately four wavelengths, and FIG. 5 shows the degradation produced in a substantially omnidirectional pattern by the presence of such a boom. As can be seen in FIG. 5, the substantially omnidirectional pattern is broken into a series of lobes and nulls.

By means of the present invention, the deterioration of the omnidirectional pattern as seen in FIG. 5 is substantially eliminated, as may be seen in the schematic representation of FIG. 6, which shows the substantially omnidirectional characteristic achieved by means of the apparatus of this invention.

The invention has been described above in some detail in connection with a preferred embodiment thereof. However, it will be apparent to those skilled in the art that other suitable specific means may well be employed within the inventive concept disclosed herein, wherein radiation from an antenna associated with a relatively long conductive support or the like is limited to a predetermined and relatively small segment thereof. Hence, the invention is not to be considered as limited to the particular details given, nor to the specific application to which reference has been made during the description of the invention, but should be considered as extending to encompass all such revisions and modifications as would be obvious to a workman of ordinary skill in the art.

What is claimed is:

1. An antenna for providing an omnidirectional pattern in an environment which includes conductive members which are long relative to a wavelength of the electromagnetic energy for which the antenna is designed comprising: a plurality of conductive members relatively positioned in a given radiating array, at least one of said conductive members being longer than a predetermined length with respect to the wavelength for which the antenna is designed, said predetermined length being one-quarter of the wavelength for which the antenna is designed, the remaining conductive members being at least of such predetermined length, means for applying electrical energy to said conductive members to effect radiation of electromagnetic energy therefrom, and means for limiting the radiation from each said longer conductive member to a portion thereof equal to such predetermined length, said means for limiting the radiation from each said longer conductive member comprising a cylindrical conductive member of a length equal to one-quarter of such wavelength, said cylindrical member comprising a flexible conductive material adapted to fold upon itself to a foreshortened configuration for compact storage, means for supporting said cylindrical member in coaxial relationship with such longer conductive member in electrically insulated relationship therewith, and means for shorting one end of said cylindrical member to such longer conductive member adjacent one end of the latter, whereby the non-shorted end of said cylindrical member constitutes an open circuit to such electromagnetic energy propagated therealong, thereby preventing the propagation of such energy beyond said non-shorted end.

2. An antenna for providing an omnidirectional pattern in an environment which includes conductive members which are long relative to a wavelength of the electromagnetic energy for which the antenna is designed in accordance with claim 1, and including means for urging said flexible conductive material into a fully extended condition.

3. An antenna for providing an omnidirectional pattern in an environment which includes conductive members which are long relative to a wavelength of the electromagnetic energy for which the antenna is designed in accordance with claim 2, wherein said means for urging said flexible material to its extended condition comprises a helical resilient member.

4. An antenna for providing an omnidirectional pattern in an environment which includes conductive members which are long relative to a wavelength of the electromagnetic energy for which the antenna is designed comprising: a plurality of linear conductive members relatively positioned in a turnstile radiating array, at least one of said linear conductive members being longer than a predetermined length with respect to the wavelength for which the antenna is designed, the remaining linear conductive members being at least of such predetermined length, said predetermined length being one-quarter of the wavelength for which the antenna is designed, means for applying electrical energy to said linear conductive members to effect radiation of electromagnetic energy therefrom, and means for limiting the radiation from each said longer linear conductive member to a portion thereof equal to such predetermined length, said means for limiting the radiation from each said longer linear conductive member comprising a cylindrical conductive member of a length equal to one-quarter of such wavelength, said cylindrical member comprising a flexible conductive material adapted to fold upon itself to a foreshortened configuration for compact storage, means for supporting said cylindrical member in coaxial relationship with such longer linear conductive member in electrically insulated relationship therewith, and means for shorting one end of said cylindrical member to such longer linear conductive member adjacent one end of the latter, whereby the non-shorted end of said cylindrical member constitutes an open circuit to such electromagnetic energy propagated therealong, thereby preventing the propagation of such energy beyond said non-shorted end.

5. An antenna for providing an omnidirectional pattern in an environment which includes conductive members which are long relative to a wavelength of the electromagnetic energy for which the antenna is designed in accordance with claim 4, and including means for urging said flexible conductive material into a fully extended condition.

6. An antenna for providing an omnidirectional pattern in an environment which includes conductive members which are long relative to a wavelength of the electromagnetic energy for which the antenna is de-

signed in accordance with claim 5, wherein said means for urging said flexible material to its extended position comprises a helical resilient member.

7. An antenna comprising: a first conductive member which is longer than a predetermined length; a second conductive member positioned adjacent said first conductive member and substantially equal in length to said predetermined length, said second member comprising a flexible conductive material adapted to fold upon itself to a foreshorted configuration for compact storage; means for applying electrical energy to said second conductive member to effect radiation of electromagnetic energy therefrom; and means connecting said first conductive member with said second conductive member and cooperating with said second conductive member for preventing said electrical energy from passing to a portion of said first conductive member.

8. An antenna comprising: an elongated conductor which is longer than a predetermined length; a hollow cylindrical conductive member displaying an axial length equal to said predetermined length and positioned coaxially around said conductor, said cylindrical member comprising a flexible conductive material adapted to fold upon itself to a foreshorted configuration for compact storage; means for applying electrical energy to said cylindrical member to effect radiation of electromagnetic energy therefrom; and electrically conductive means connected to one end of said cylindrical member and to said conductor at a point adjacent said one end whereby said cylindrical conductor acts as an electrical choke for preventing said electrical energy from passing to that portion of said conductor extending outside said cylindrical member.

9. An antenna for providing an omnidirectional pattern, comprising: a plurality of elongated conductive members at least one of which is longer than a predetermined length, said elongated members being orthogonally positioned with respect to one another and having inner portions adjacent to one another; a plurality of hollow cylindrical conductive members each of which displays an axial length equal to said predetermined length, each of said cylindrical members being positioned coaxially with and surrounding the inner portion of a different one of each of said elongated members so that said cylindrical members are mutually orthogonally positioned and each has an inner end adjacent to the inner ends of said other cylindrical members; means for applying electrical energy to each of said cylindrical members near said inner ends thereof to effect omnidirectional pattern radiation of electromagnetic energy from said cylindrical members; and electrically conductive means connecting said inner ends of each of said cylindrical members to said inner portion of said elongated members whereby said cylindrical members act as electrical chokes for preventing said electrical energy from passing to those portions of said elongated members extending outside said cylindrical members.

10. An antenna according to claim 9 wherein said predetermined length is one-quarter of the wavelength for which the antenna is designed.

11. An antenna according to claim 10 wherein said cylindrical member comprises a flexible conductive material adapted to fold upon itself to a foreshorted configuration for compact storage.

* * * * *