United States Patent [19]

Campbell et al.

[11] **3,879,735**

[45] **Apr. 22, 1975**

[54] **BROADBAND ANTENNA SYSTEMS WITH ISOLATED INDEPENDENT RADIATORS**

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[21] Appl. No.: **472,322**

[52] **U.S. Cl.** **343/792;** 343/821
[51] **Int. Cl.** **H01q 9/16**
[58] **Field of Search** 343/792, 801, 807, 821

[56] **References Cited**

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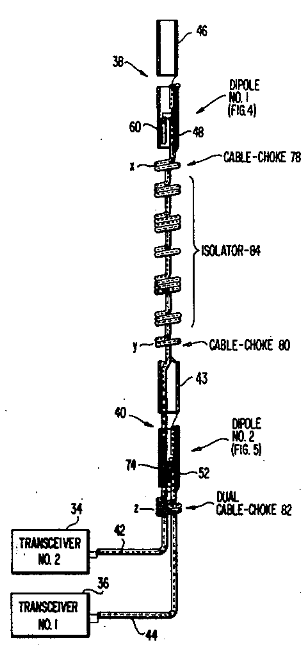
3,680,146 7/1972 Leitner 343/792

Primary Examiner—Eli Lieberman
Attorney, Agent, or Firm—Nathan Edelberg; Robert P. Gibson; Jeremiah G. Murray

[57] **ABSTRACT**

A dipole array consisting of at least two dipole antennas mounted one above the other in a generally vertical plane, having respective pairs of radiating elements substantially aligned on a common generally vertical axis and being fed from respective radio signal sources by the respective feed lines directed along the common vertical axis through the various radiating elements and being configured to also include a cable choke section on either side of the lower antenna as well as a cable choke section below the upper antenna. An isolator section comprised of a plurality of series connected cable choke sections are located intermediate each dipole antenna. Additionally, an impedance characteristic compensating network consisting of a predetermined length of transmission line is connected to each dipole feed line within one of the radiating elements of each dipole antenna.

12 Claims, 8 Drawing Figures



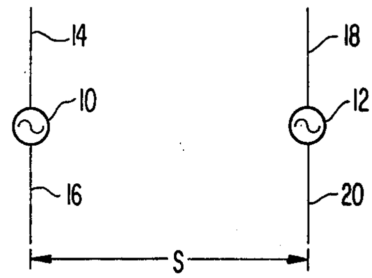


FIG. 1B

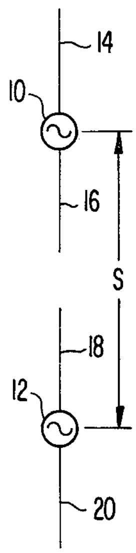


FIG. 1A

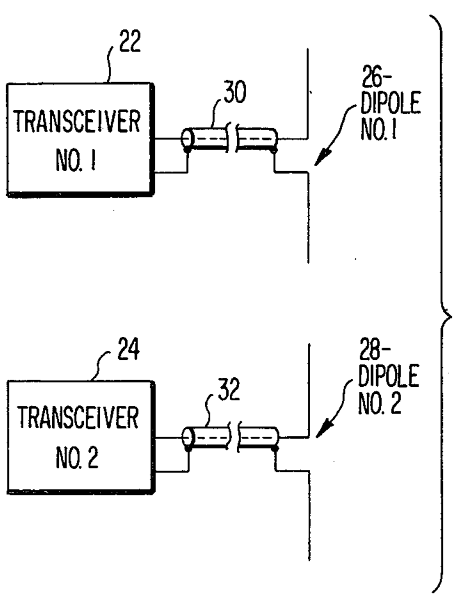


FIG. 2
(PRIOR ART)

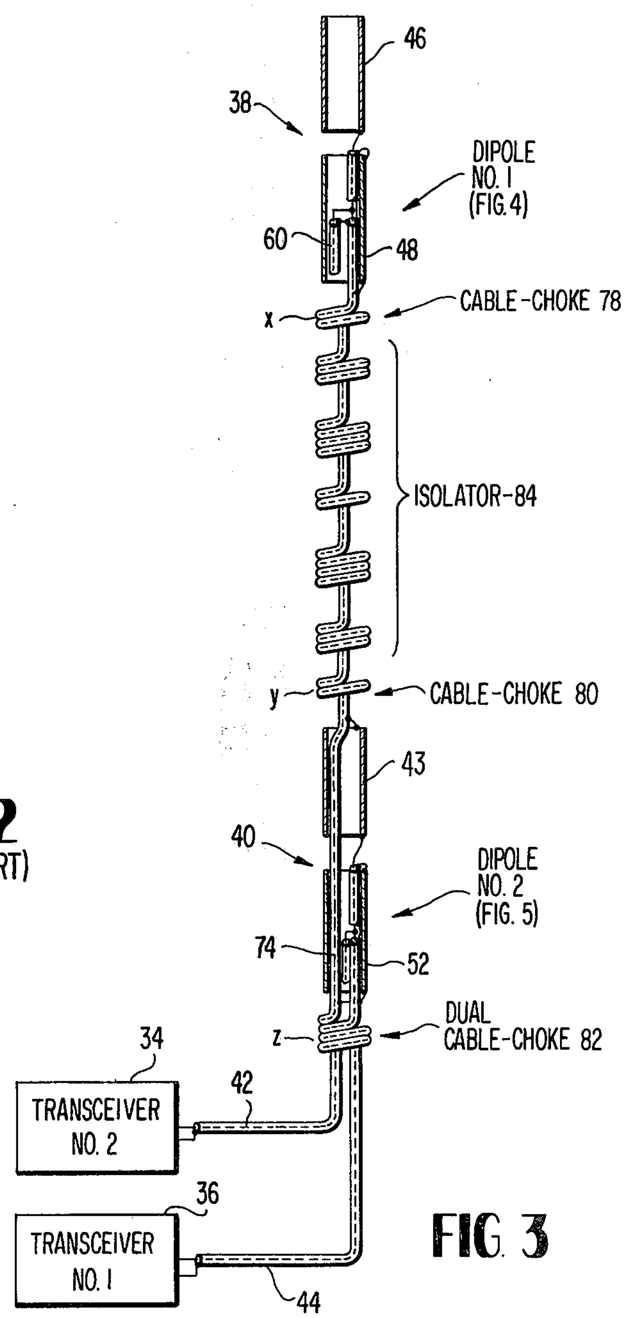


FIG. 3

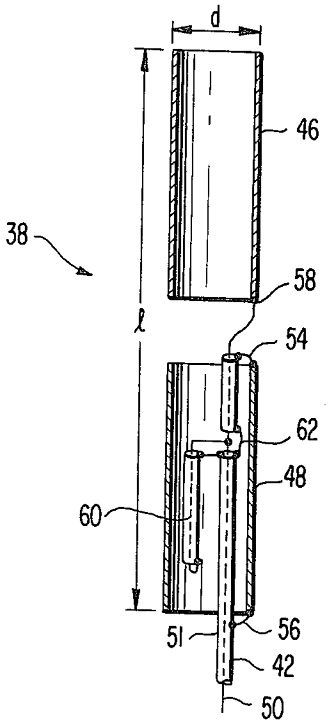


FIG. 4

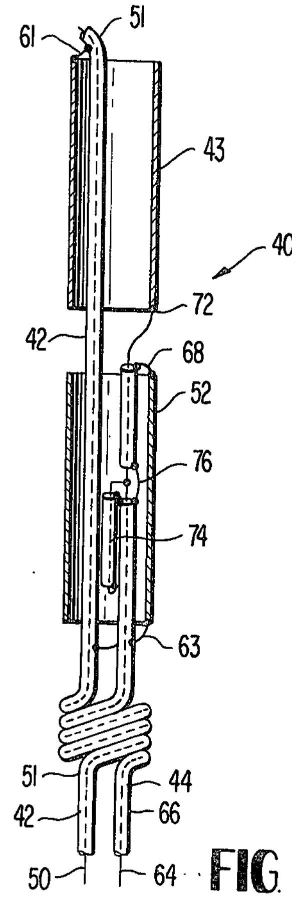
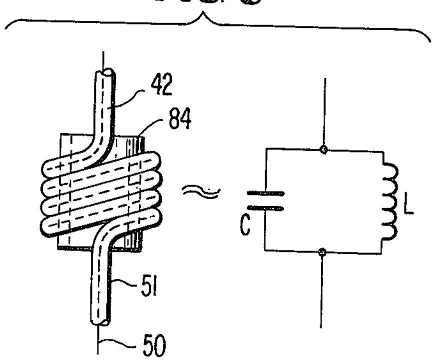


FIG. 5

FIG. 6



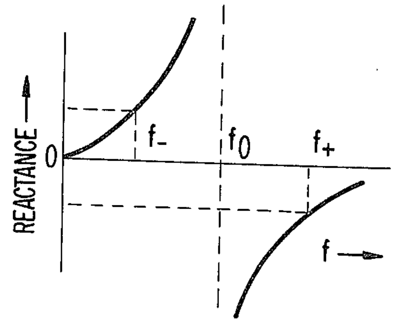


FIG. 7

BROADBAND ANTENNA SYSTEMS WITH ISOLATED INDEPENDENT RADIATORS

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

BACKGROUND OF THE INVENTION

The present invention relates generally to antennas of electromagnetic radiation and more particularly to a dipole antenna array wherein one or more antennas are operated from different radio transmitters.

When several radio signal sources such as transceivers are operated simultaneously in close proximity, it is common to experience receiver overload, desensitization, cross talk, or other annoying non-linear effects arising from cross modulation occurring in the receivers. These disturbances are caused by the comparatively intense electromagnetic fields in the immediate neighborhood of the respective antennas. Even though the respective transceivers are properly shielded and are operated on widely separated frequencies, cross modulations still occur because of the strong antenna interaction.

It is well known that electrical isolation between two dipole antennas fed from separate radio signal sources is significantly greater when the dipoles are mounted one above the other on the same axis as opposed to being arranged in a broadside relationship, with the same relative spacing between feed points. However, even where the dipoles are mounted one above the other, the respective transmission lines are generally connected from the radio signal sources to the dipole antennas without any regard to the fact that the physical arrangement of the feed transmission lines themselves plays a significant role in determining the radiation characteristic, the impedance and the electrical isolation between the dipoles.

The following patents constitute known prior art:

2,115,761 — A. D. Blumlein
2,158,376 — W. Moser, et al.
2,425,585 — H. A. Wheeler

SUMMARY

The antenna system comprising the subject invention is particularly adapted but not restricted for use in the UHF range of the electromagnetic spectrum existing between 225 and 400 MHz. When desirable, operation is also possible at other frequencies as well, for example the VHF range existing between 115 and 150 MHz. The antenna system comprising the subject invention is directed to an improvement in broadband antenna systems for separate and diverse radio signal sources while providing broad frequency range and minimum cross talk between communication systems providing simultaneous transmission and reception.

Briefly, the subject invention is directed to a common dipole array for at least two separate transceivers adapted to operate simultaneously, consisting of a plurality of dipole antennas (at least two) having minimized electromagnetic coupling therebetween by being mounted one above the other in a generally vertical plane and having respective preferably tubular radiation element pairs substantially aligned along a common generally vertical axis. The two radio transceivers are coupled to a respective dipole by means of a separate feedline. The respective feedlines are directed along the common vertical axis through the tubular radiating elements to the respective dipole feed points. The feedline for the upper dipole is selectively configured to provide a cable choke on the lower side of the upper dipole and on either side of the lower dipole as well as an isolator section between each dipole. The feedline for the lower dipole is also configured to provide a cable choke on the lower side of the lower dipole in common with the choke thereat formed in the feedline for the upper dipole. An impedance compensating network comprising a predetermined length of transmission line is also connected to each dipole feedline within one of the respective dipole radiating elements.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A** and **1B** are schematic diagrams illustrative of two possible mounting configurations for two dipole antennas which are separately fed from diverse RF generators;

FIG. **2** is a schematic diagram illustrative of a pair of axially aligned dipole antennas fed in accordance with prior art practice;

FIG. **3** is a diagram illustrative of the preferred embodiment of the subject invention;

FIG. **4** is a diagram further illustrative of the upper dipole antenna illustrated in FIG. **3**;

FIG. **5** is a diagram further illustrative of the lower dipole antenna shown in FIG. **3**;

FIG. **6** is a diagram illustrative of a cable choke and its equivalent electrical circuit; and

FIG. **7** is a diagram illustrative of the reactance vs. frequency characteristic of the cable choke shown in FIG. **6**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An antenna is a conductor so constructed as to either radiate electromagnetic energy, to collect electromagnetic energy, or to do both. A transmitting antenna converts electrical energy into electromagnetic waves called radio waves which radiate away from the antenna at speeds near the velocity of light. A receiving antenna converts electromagnetic waves which it intercepts into electrical energy and applies this energy to electronic circuits for interpretation. Some antennas such as that concerned with the subject invention are adapted to serve both functions.

The electrical and physical features of antennas are moreover determined by the use to which they are put. Such features will vary with operating frequency, power handling capability, plane of polarization and desired radiation field pattern. The physical size of an antenna is determined primarily by its operating frequency and power handling capability while its shape and height are determined by the desired radiation field pattern. A half-wave dipole antenna is not only a fundamental element in an antenna system, it is particularly adapted for communications use in applications above 2MHz (2×10^6 Hertz). Basically the half wave dipole antenna is comprised of two quarter wave conductors linearly aligned and having the inner extremities excited by an RF generator. Such apparatus is well known to those skilled in the art and is well documented in all the literature dealing with the fundamentals of radio transmission.

The subject invention is directed to the problem of minimizing cross talk between several RF generators and more particularly radio transceivers operated simultaneously in close proximity to one another. Reference is now made to FIGS. 1A and 1B wherein two radio signal sources **10** and **12** are separated by a spacing S. The source **10** is coupled to dipole radiating elements **14** and **16** while source **12** is coupled to dipole elements **18** and **20.** The system shown in FIG. 1A is illustrative of the configuration wherein the dipoles are mounted one above the other and being substantially aligned along a common generally vertical axis, whereas the configuration in FIG. 1B illustrates the configuration where the elements are arranged in a broadside arrangement wherein the dipole elements **14** and **16** define one common vertical plane while the dipole elements **18** and **20** define a second parallel vertical plane.

It can be shown that it is more desirable when operating the separate radio signal sources **10** and **12** separately, to resort to the configuration shown in FIG. 1A since the electrical isolation between the dipole elements when so arranged is significantly greater than that obtained with the configuration shown in FIG. 1B. The schematic representations shown in FIGS. 1A and 1B are idealized because separate transmission lines must be utilized to connect the dipole elements to the respective sources.

A typical prior art configuration for operating a plurality of tranceivers in relative close proximity is shown in FIG. **2,** wherein for example a first and second radio transceiver **22** and **24** are coupled to respective dipole antennas **26** and **28** by means of the feedline transmission lines **30** and **32.** When transmission lines are present, the radiating system not only consists of the dipole antennas **26** and **28,** but also the respective interconnecting feedlines **30** and **32.** Such an arrangement has certain inherent limitations since the physical arrangement of the transmission lines plays a significant part in determining the antenna radiation characteristic, the impedance, and the electrical isolation between the dipole antennas.

Recognizing the reduction of electromagnetic coupling achieved by the arrangement shown in FIG. 1A, the inventive concept of the subject invention is disclosed in a configuration shown in FIG. **3,** wherein reference numerals **34** and **36** designate a pair of transceivers which are coupled to respective dipole antenna assemblies **38** and **40** which are mounted one above the other along a common generally vertical axis. The upper dipole antenna assembly **38** is further illustrated in FIG. **4,** while the lower dipole assembly **40** is further illustrated in FIG. **5.** The transceiver **34** is coupled to the upper dipole antenna assembly **38** by means of feedline **42** which comprises a coaxial transmission line while the second transceiver **36** is coupled to the lower dipole assembly **40** by means of feedline **44** which is also a coaxial transmission line.

The dipole assemblies **38** and **40** used in the system shown in FIG. **3** are substantially identical and include pairs of tubular radiating elements **46** and **48,** and **43** and **52** respectively, which are composed of thin walled aluminum tubing or other desired light weight metallic material. Referring briefly now to FIG. **4,** the length (l) to outer diameter (d) ratio l/d of any tubular radiating element has a considerable effect on the reactive component of its feed-point impedance which is at the point of connection of the feedline to the two dipole radiating elements. Relatively fat dipole radiating elements comprised of tubing of a relatively large diameter, resulting in a small l/d ratio, normally provides a smoother impedance characteristic than thin dipole elements as frequency is varied. However, in applications where size, weight, etc. must be minimized, thin dipole elements nevertheless become desirable. In such cases a compromise is usually made in which a suitable impedance characteristic is obtained over the required frequency range by the coupling of special compensating networks in series or in parallel with the dipole feedline.

Accordingly, the subject invention is comprised of dipole elements having a sufficient inner diameter dimension so that at least one transmission line acting as a feedline can pass therethrough and a compensating network can be installed inside one of the radiating elements. Directing attention now more particularly to the first dipole antenna assembly **38** shown in FIG. **4,** the dimensions of the two tubular radiating elements **46** and **48** are substantially alike, being axially aligned in a vertical plane by means of structural supports, not shown. Such supports form no part of the subject invention and are clearly within the purview of one skilled in the art. The feedline **42** being comprised of a coaxial transmission line having an inner conductor **50** and an outer conductor **51,** passes through the lower element **48** preferably as close to its center axis as possible. The outer conductor **51** is electrically connected to the lower element at both ends thereof by the electrical connections **54** and **56** while the inner conductor **50** is exposed after passing through the lower radiating element **48** and is electrically connected to one end of the upper element **46,** i.e. the lower end thereof at contact point **58.** Inasmuch as a design trade off is ordinarily required in order to meet the desired physical requirements, the lower dipole element **48** includes a coaxial transmission line impedance matching stub **60** installed inside of the lower element **48,** having its inner and outer conductors respectively coupled to the inner conductor **50** and the outer conductor **51** of the feedline **42** at the location **62** intermediate the length of the radiating element **48.** Additionally there is a short between the inner and outer conductors at the lower end of the stub.

The second or lower dipole antenna assembly **40** as shown in FIG. **5** is shown as being similar in physical dimensions to the upper antenna assembly **38**; however, it should be observed that this is shown for purposes of illustration and is not meant to be interpreted in a limiting sense since the specific design considerations may require somewhat different dimensions than being substantially identical to the upper antenna assembly. What is significant about the lower dipole antenna assembly **40** is that the feedline **42** for the upper dipole assembly **38** passes, preferably centrally, through both tubular radiating elements **43** and **52** with the outer conductor **51** being electrically connected to the top portion of element **43** by connection **61** and the lower portion element **52** by connection **63.** Additionally, the coaxial transmission line feed **44** comprised of an inner conductor **64** and an outer conductor **66** couple the transceiver **36** to the radiating elements **43** and **52** in the same manner that the transceiver **34** is coupled to the upper dipole elements **46** and **48.** More particularly, the outer conductor **44** is connected to the lower dipole element **52** at both the upper and lower extremities by connections **68** and **63.** The inner conductor **64** couples to the upper dipole element 43 at contact point 72 which is at the lower end of the element. As in the case of the upper antenna 38, the lower antenna assembly 40 also includes a broadband transmission line compensating network comprised of a coaxial transmission line stub 74 located inside the lower radiating element 52 and being coupled to the inner and outer conductors 64 and 66 at location 76. As in the earlier mentioned stub 60, the inner and outer conductors of the stub 74 are connected together at the lower end thereof. It is to be noted that the feedline 42 for the upper antenna assembly 38 in effect places two series connected shorted transmission line stubs in parallel with the dipole feed point of the lower dipole antenna assembly 40. The effect of this shunt requires somewhat different values for the impedance compensator comprising the transmission line stub 74. However, it is possible to obtain adequate compensation over an octave bandwidth with proper design of the stubs 60 and 74.

In order to provide an operable arrangement for the axially aligned dipole assemblies 38 and 40 with the corresponding feed-through of the coaxial transmission lines 42 and 44 as shown in FIGS. 3, 4 and 5, it is necessary to provide regions of high impedance at points x, y and z (FIG. 3) in order to reduce electrical excitation of the feedline 42 by both sets of dipole elements 46 and 48, 43 and 52 and feedline 44 by the lower set of dipoles 43 and 52, and to establish the correct electrical length of respective dipoles. This is provided by cable chokes 78, 80 and 82 formed in the feedline 42, the cable choke 82 being a dual or composite cable choke formed in combination with the feedline 44. Additionally, an isolator section 84 formed in the feedline 42 is included between points x and y, i.e. between the cable chokes 78 and 80 in order to minimize excitation of the section of feedline 42 between the two dipole antennas 38 and 40. The isolator section 84 consists of a plurality of selectively configured series connected cable chokes along its length between the points x and y. Referring now to FIGS. 6 and 7, a cable choke comprises winding a portion of a coaxial transmission line, for example the feedline 42, on a small ferrite toroidal core 84. When desirable at frequencies in the UHF range, it is often desirable to delete the ferrite core 84 and wind the transmission line into a circular cylinder. In either case, at certain frequencies it acts electrically as if it were a high impedance circuit. Its electrical equivalent circuit comprises a parallel combination of an inductance L and a self-capacitance C with its reactance being a function of frequency f as shown in FIG. 7. Referring now to FIG. 7, the self capacitance C and the inductance L of the cable choke portion becomes parallely resonant at a frequency $f_o = 1/(2\pi\sqrt{LC})$. At frequencies between f_- and f_+, the cable choke provides extremely high impedance to radio frequency currents flowing on the outside of the outer conductor, for example outer conductor 51. The frequencies f_+ and f_- are defined by the requirement that the cable choke provide at these frequencies a predetermined reactance which is inductive below the frequency f_o but capacitive above the frequency f_o, which may be of the order of ± 1 kilohm to ± 5 kilohm, depending upon the particular application. By minimizing the self capacitance C of the cable choke, the bandwidth $BW = (f_+ - f_-)$ can be made quite large. The cable chokes at the top and bottom of the particular dipole antenna assemblies as noted above determines its electrical length. Accordingly, these chokes are tuned to resonate substantially in the mid-frequency range of the dipole. Also as noted above, the isolator section 84 consists of several cable chokes included along the feedline 42 between the cable chokes 78 and 80. The number of cable chokes employed is at present done experimentally; as such, isolators have been constructed which typically provides an average of 45db isolation between two UHF dipole antennas operating in the frequency range of from 220 to 400MHz.

While a UHF dual antenna system including the components shown in FIG. 3 comprises a preferred embodiment, this disclosure has been made by way of illustration only, and is not meant to be interpreted in a limiting sense. Hence, certain modifications and alterations may be resorted to without departing from the spirit and scope of the invention. For example, it is apparent that an antenna system according to the subject invention can be assembled from separate modules connected at the points marked x and y in FIG. 3. For such modules, a variety of such antenna systems can be assembled for various frequency ranges, including the VHF range as well as UHF. Furthermore, if more than two dipole antennas are required, multiple feed-through lines and multiple cable chokes would be employed in the manner as taught by the subject disclosure. Finally, in installations where isolation between dipole antennas is of secondary importance or where different frequency ranges are employed for the separate antennas, the isolator section 84 shown in FIG. 3 can be shortened or suitably modified or even eliminated in certain instances.

Accordingly, we claim as our invention:

1. A broadband antenna system for at least first and second radio apparatus adapted to operate simultaneously in relative close proximity, comprising in combination:

at least two dipole antennas, each including a pair of radiating elements, respectively coupled to said first and second radio apparatus, said antennas being mounted one above the other and having a predetermined spacing therebetween with said respective pairs of radiating elements being aligned generally along a common vertical axis;

a first transmission feedline coupling said first radio apparatus to the upper dipole antenna, running through the pair of radiating elements of said lower dipole antenna and the lower radiating element of said upper dipole antenna and additionally being configured to provide a first cable choke section adjacently below the lower radiating element of the upper dipole antenna, a second cable choke section adjacently above the upper radiating element of the lower dipole antenna, and a third cable choke section adjacently below the lower radiating element of the lower dipole antenna;

a second transmission feedline coupling said second radio apparatus to the lower dipole antenna, being fed through the lower radiating element thereof, and configured to provide a fourth cable choke section adjacently below the lower radiating element of said lower dipole antenna; and

impedance matching networks located inside of one element of each of said two dipole antennas, being respectively coupled to said first and second transmission feedlines for adjusting the impedance characteristic of the feed point of said two dipole antennas.

2. The antenna system as defined by claim **1** wherein said first transmission feedline is additionally configured to include an isolation section comprised of the plurality of cable choke sections located intermediate said first and second cable choke section.

3. The antenna system as defined by claim **1** wherein said third and fourth cable choke sections are configured contiguously to provide a composite cable choke section.

4. The antenna system as defined by claim **3** wherein said first transmission line is configured to additionally provide an isolator section comprising a plurality of selectively configured cable choke sections intermediate said first and second cable choke section.

5. The antenna system as defined by claim **4** wherein each pair of radiating elements is comprised of radiating elements having a relatively large length to width ratio.

6. The antenna system as defined by claim **1** wherein said first and second transmission feedlines are each comprised of coaxial transmission lines having inner and outer conductors, the inner conductor of said first transmission line being electrically connected to the lower portion of the upper radiating element of the upper dipole antenna and the outer conductor thereof being electrically connected to the upper and lower portion of the lower radiating element of said upper dipole antenna, as well as the upper portion of the upper radiating element and the lower portion of the lower radiating element of the lower dipole antenna; and

wherein said inner conductor of said second transmission line is electrically connected to the lower portion of the upper radiating element of the lower dipole antenna and the outer conductor thereof is electrically connected to the upper and lower portion of the lower radiating element of said lower dipole antenna.

7. The antenna system as defined by claim **6** wherein said compensating networks for said two dipole antennas comprises transmission line means located inside the lower radiating element of said two dipole antennas and being coupled to the respective first and second transmission line therein.

8. The antenna system as defined by claim **7** wherein said compensating means comprises a stub of coaxial transmission line having an inner and outer conductor respectively connected to the inner and outer conductor of the respective transmission line.

9. The antenna system as defined by claim **1** wherein said first, second, third and fourth cable choke sections are comprised of a predetermined number of windings of said transmission lines wound on a respective magnetic core.

10. The antenna system as defined by claim **9** wherein said cores comprise toroids of ferrite material.

11. The antenna system as defined by claim **1** wherein said first and second radio apparatus comprise transceivers operable in the megahertz range of radio frequencies.

12. The antenna system as defined by claim **1** wherein one of at least said two dipole antennas is comprised of a pair of UHF dipole radiating elements, the one of said first and second radio apparatus coupled thereto comprises a transceiver operative in the UHF frequency range.

* * * * *