July 20, 1943. H. A. WHEELER 2,324,548

DIRECTIVE ANTENNA SYSTEM

Filed Sept. 18, 1941

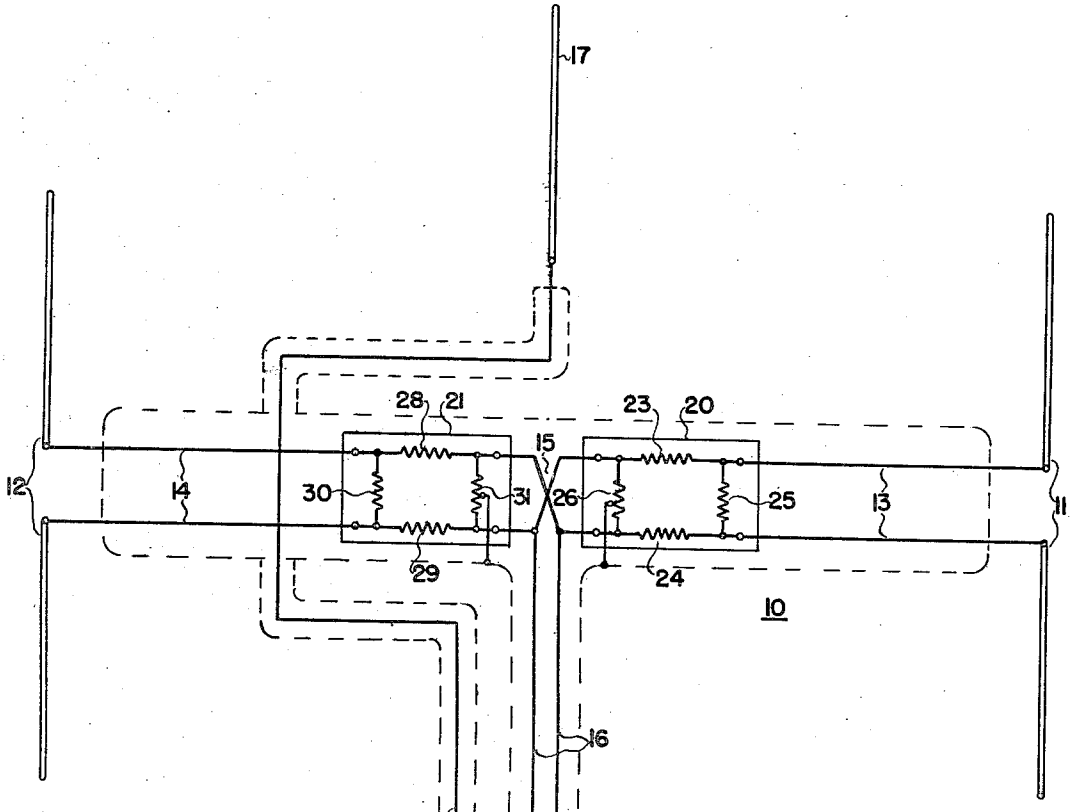
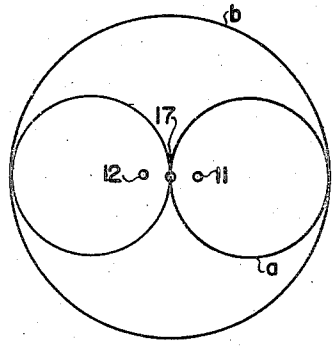


FIG. 2.



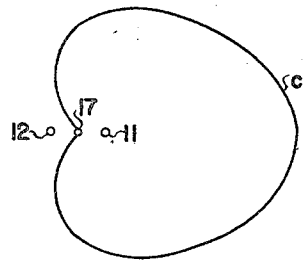


FIG. 3.

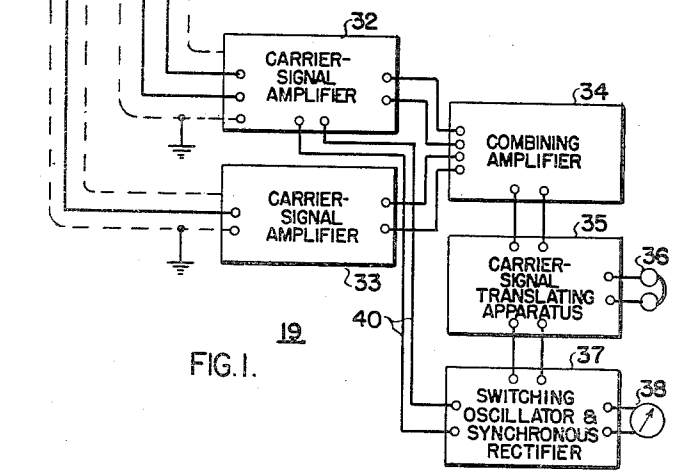


FIG. 1.

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DIRECTIVE ANTENNA SYSTEM

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8 Claims. (Cl. 250—33)

The present invention relates to directive antenna systems and, particularly, to directive antenna systems of the Adcock type. More particularly, the invention relates to directive antenna systems having a directive characteristic approximately of cardioid configuration.

The Adcock antenna of the prior art comprises a pair of spaced vertical dipole antennas interconnected by a crossed transmission line and has a horizontal directive characteristic of the well-known figure-eight type. It has heretofore been the practice in using this type of antenna to operate the antenna at frequencies below the lowest natural frequency thereof. If it is desired that an Adcock antenna be operated over a wide frequency band, the highest frequency of the band must, in accordance with such prior-art practices, be lower than the lowest natural frequency of the antenna. In such case, the lowest frequency of the operating-frequency band is far below the range of efficient operation of the Adcock antenna. It would be desirable for efficient operation of the Adcock antenna over such a wide frequency band that some of the natural resonant frequencies of the antenna be permitted to fall within the band. This is especially true for ultra-high-frequency bands, for example, a band from 18 to 65 megacycles or from 65 to 140 megacycles.

However, when an Adcock antenna is operated at a frequency near its lowest natural frequency of resonance, or any other odd-order natural frequency thereof, a current maximum occurs at or near the center of the transmission line which interconnects its dipole antennas with the result that any slight electrical unbalance of the components of the antenna with relation to the point at which the lead-in transmission line is coupled thereto is greatly amplified and undesirably distorts the figure-eight pattern which is characteristic of this type of antenna. Exact electrical balance between the components of the Adcock antenna is therefore required and is difficult to attain in practice.

Certain directive antenna systems of the prior art employ in combination with the Adcock antenna a non-directive antenna, generally of the vertical type, positioned midway between the Adcock vertical dipoles. An antenna system of this nature can be made to have a directive characteristic approximately of cardioid configuration. Such antenna systems also are satisfactory when operated at a frequency below the lowest natural resonant frequency of the Adcock antenna. It is frequently desirable, however, that the antenna system be operated over a frequency band which may include one or more of the natural resonant frequencies of the Adcock antenna. In this event, the difficulties previously noted arise from using the Adcock antenna in this manner and there is the additional problem of the incidental transfer of carrier-signal energy at certain operating frequencies to the Adcock antenna from the nondirective antenna associated therewith. The reradiation of this incidentally transferred energy from the Adcock antenna causes undesirable and sometimes extreme irregularities in, or distortion of, the directive characteristic of the nondirective antenna. This impairment of the normally nondirective characteristic of the latter antenna results in serious impairment at these operating frequencies of the cardioid directive characteristic which is desired of the antenna system over the wide range of operating frequencies. This desired range, as previously noted, includes the natural resonant frequencies of the Adcock antenna at which the impairment of the directive characteristic of the antenna system is greatest.

It is an object of the invention, therefore, to provide a directive antenna system of the Adcock type having a desired directive characteristic which is substantially the same at any selected operating frequency over a comparatively wide range of frequencies which may include one or more of the odd-order natural resonant frequencies of the Adcock antenna and one which avoids one or more of the disadvantages and limitations of the prior art systems.

It is a further object of the invention to provide a directive antenna system of the Adcock type wherein the desired directive characteristic of the system is maintained over a wide range of operating frequencies which may include one or more of the natural resonant frequencies of the Adcock antenna, and one in which the desired directive characteristic is not seriously impaired by electrical unbalances of the components of the Adcock antenna used in this system.

It is an additional object of the invention to provide an antenna system comprising an Adcock antenna and a centrally-located vertical antenna in which the nondirective characteristic of the latter antenna is maintained without regard to the presence in close proximity thereto of the Adcock antenna and one in which this is especially maintained near the natural resonant frequencies of the Adcock antenna.

It is a further object of the invention to pro-

vide a directive antenna system having a directive characteristic of cardioid configuration substantially the same over a wide range of operating frequencies including one or more natural resonant frequencies of the antenna system.

In accordance with the invention, a directive antenna system comprises an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission line in series and cross-connected at their junction. A balanced lead-in transmission line is coupled to the two sections at the junction thereof. The Adcock antenna has natural resonant frequencies in the vicinity of the band of frequencies over which the system is to be operated. The antenna system includes also means for reducing at predetermined operating frequencies the disturbing effect on the directive characteristic of the Adcock antenna of electrical unbalances of the components thereof with relation to the point at which the lead-in transmission line is coupled thereto comprising resistive means included in each of the transmission line sections and having at least one effectively resistive element in the series paths of the above-mentioned sections which interconnect the pair of dipoles.

In accordance with a particular form of the invention, a directive antenna system of the type described includes, in addition to the Adcock antenna, a nondirective antenna centrally positioned with respect to the dipoles of the Adcock antenna and a lead-in transmission line coupled to the nondirective antenna. This antenna system includes means for reducing the pickup of carrier-signal energy by the Adcock antenna from the nondirective antenna, and the consequent reradiation of such energy, in the vicinity of operating frequencies corresponding to odd-order natural frequencies of the Adcock antenna comprising a resistive network included in each of the transmission line sections of the Adcock antenna.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring now to the drawing, Fig. 1 is a circuit diagram, partly schematic, of an antenna system embodying the invention; Fig. 2 is a graph representing the directive characteristic of each of the antennas comprising the antenna system of Fig. 1; and Fig. 3 is a graph representing a directive characteristic which may be obtained from the arrangement of Fig. 1.

Referring now more particularly to Fig. 1, there is represented schematically a complete carrier-signal translating system of a conventional design embodying the present invention in a preferred form. In general, the system includes an Adcock antenna 10 comprising a pair of spaced parallel vertical dipoles 11, 12 interconnected by two sections 13, 14, respectively, of balanced transmission line in series and cross-connected at their junction 15. A lead-in balanced transmission line 16 is coupled to the two transmission-line sections 13, 14 at the junction 15 thereof. The Adcock antenna 10 is designed to have natural resonant frequencies in the vicinity of the band of frequencies over which the carrier-signal translating system is to be operated; specifically, in an ultra-high-frequency operating band, the natural resonant frequencies of the Adcock antenna 10 may lie within and extend over a substantial portion of the operating frequency band.

The system of Fig. 1 includes also a nondirective vertical antenna 17 parallel with and centrally positioned with respect to the dipoles 11, 12 of the Adcock antenna 10. A lead-in unbalanced transmission line 18 is coupled to the nondirective antenna 17. The two sections 13, 14 of balanced transmission line and the two lead-in transmission lines 16 and 18 are individually provided with grounded conductive shields as indicated by the broken lines surrounding these transmission lines. The transmission lines 16 and 18 are coupled to individual circuits of a carrier-signal translating apparatus 19 which may be either a receiving or transmitting apparatus depending upon the use to which the translating system is to be put.

A carrier-signal translating system of the receiver type is disclosed and claimed in the copending application of Robert L. Freeman et al., Serial No. 414,738 filed October 13, 1941, and assigned to the same assignee as the present application. In a receiver system of this nature, unit 19 includes a pair of input amplifiers 32, 33 having input circuits coupled to the transmission lines 16 and 18, respectively. The outputs of the amplifiers 32, 33 are applied in parallel to the input circuit of a combining amplifier 34, to the output circuit of which is coupled a carrier-signal translating apparatus or channel 35. The latter includes one or more stages of carrier-signal amplification, a detector, and one or more stages of audio-frequency amplification. Coupled to the output circuit of the audio-frequency amplifier of unit 35 is a sound-reproducing device 36 and an audio-frequency switching oscillator and synchronous rectifier 37. The synchronous rectifier of unit 37 has an output circuit which is coupled to a visual indicating device or meter 38 of the zero-center-scale direct-current type and includes synchronizing control circuits which are coupled to the output of the audio-frequency switching oscillator of unit 37. The oscillations generated by the audio-frequency switching oscillator of unit 37 are also applied through circuits comprising conductors 40 to switching circuits of the carrier-signal amplifier 32.

The carrier-signal translating system includes means for reducing to a minimum at predetermined operating frequencies the disturbing effect on the directive characteristic of the Adcock antenna 10 of electrical unbalances of the components thereof with relation to the point at which the lead-in transmission line 16 is coupled thereto comprising resistive means 20, 21 individually included in the transmission line sections 13, 14, respectively.

It will be understood that the various units just described may, with the exception of the resistive means 20, 21 be of a conventional construction and operation, the details of which are well known in the art, rendering detailed description thereof unnecessary. Considering briefly the operation of the carrier-signal translating system as a whole, and neglecting for the moment the modified operation thereof effected by the resistive means 20, 21, presently to be described, a desired carrier signal is received, for example, by the antennas 10 and 17 and applied through the respective transmission lines 16 and 18 to the respective carrier-signal amplifiers 32 and 33 of the signal-translating apparatus 19. The carrier signal applied to the carrier-signal

amplifier 33 is amplified therein and applied to the input circuit of the combining amplifier 34. The carrier signal applied to the input circuit of the carrier-signal amplifier 32 is amplified therein and also applied to the input circuit of the combining amplifier 34 with such phase relative to the amplified carrier signals from unit 33 as to provide the desired directive characteristic of the system. The phase of the carrier signal amplified by unit 32 is periodically reversed at an audio-frequency rate, thereby to reverse the directive character of the system, by the audio-frequency oscillations applied to the switching circuits of amplifier 32 from the audio-frequency switching oscillator of unit 37. The combined carrier signals are amplified by unit 34 and applied to the input circuit of the carrier-signal translating apparatus 35. The carrier signal is amplified by the carrier-signal amplifier of unit 35 and is detected by the detector thereof. The products of detection are further amplified by the audio-frequency amplifier of unit 35 and are reproduced by the sound-reproducing device 36. The amplified products of detection are also applied to the synchronous rectifier 37 which derives and applies to the indicating meter 38 an alternating current potential having half-cycles of equal amplitude when the station being received is at right angles to the dipoles 11, 12 and having maximum inequality of amplitude of the half-cycles thereof when the station is in line with the dipoles 11, 12. Since the meter 38 is of the direct-current type and consequently produces a deflection corresponding to the difference between the amplitudes of the positive and negative half-cycles of the voltage applied thereto, the deflections of the meter 38 provide an indication of the direction of the station being received.

Referring now more particularly to the portion of the system embodying the present invention, the resistive means 21 comprises a balanced resistive attenuator network having series-resistor arms 28, 29 and shunt-resistor arms 30, 31. Each of the foregoing resistive means therefore has at least one effectively resistive element in the series paths of the transmission-line sections which interconnect the pair of dipoles 11, 12. The networks 20, 21 are similar and are connected in the respective transmission-line sections 13, 14 adjacent the junction 15 thereof. The resistors 26 and 31 are grounded at their center points to the grounded metallic shield which encloses the transmission line 16. The resistor elements comprising the attenuator networks 20, 21 are proportioned to aid in matching the impedance of the transmission-line sections 13, 14 and the transmission line 16 in well-known manner. In this regard, the balanced lead-in transmission line 16 should be matched with the effective impedance of the transmission lines 13 and 14 connected in parallel.

Considering now the operation of the circuit just described, the resistive means 20, 21 play two important roles in the operation of the carrier-signal translating system. The first of these relates to the operation of the Adcock antenna 10 itself. Where the Adcock antenna 10 has resonant frequencies within the frequency band over which the system is to be operated, the Adcock antenna 10 develops a voltage minimum and a current maximum at the cross-over point 15 at each such resonant frequency. The lowest resonant frequency corresponds to a wave length equal to twice the physical length of either of the dipoles 11 or 12 and higher resonant frequencies are roughly odd multiples of the lowest resonant frequency. Any electrical unbalances of the dipole antennas 11, 12 and their respective transmission-line sections 13, 14 with relation to the point at which the lead-in transmission line 16 is coupled to the Adcock antenna 10, as at the junction 15 of the transmission-line sections 13, 14, is accentuated by the fact that a large current appears at this point. Such exaggeration of any unbalance greatly impairs the desired balance of this portion of the antenna system with a serious disturbing effect on the normal figure-eight directive characteristic, represented by curve *a* of Fig. 2 for the Adcock antenna. The resistive attenuator networks 20 and 21 serve to damp the resonance of the Adcock antenna 10, thus reducing the magnitude of the current appearing at the junction 15 at the resonant frequencies of this antenna. The damping effect of the attenuator networks 20 and 21 is a maximum when these networks are positioned in their respective transmission-line sections 13, 14 adjacent the junction joint 15 thereof. By damping the resonance characteristic of the Adcock antenna 10, the resistive networks 20 and 21 minimize the disturbing effect on the directive characteristic of antenna 10 at these resonant frequencies of accidental electrical unbalances of the components thereof with relation to the point at which the lead-in transmission line 16 is coupled thereto.

The use of two resistive network sections 20, 21 has the advantage that the sections may be positioned symmetrically in the respective transmission-line sections 13, 14 adjacent to their central junction. The resistive networks can be proportioned to aid in matching the transmission-line impedances to the down-lead line and, at the same time, effect maximum damping action to circulating resonance currents of the Adcock antenna 10 while providing minimum attenuation to the received signal translated over line 16 to the translating apparatus 19. Thus, a desired signal received by the dipoles 11, 12 passes through only one of the resistive networks 20 or 21 to the transmission line 16 whereas currents due to resonance of the Adcock antenna 10 pass through both of the resistive networks 20 and 21 in series. The amount of attenuation is not critical and, in general, the more the better insofar as the reduction of the disturbing effect of resonance of the Adcock antenna 10 is concerned. However, this attenuation does reduce the efficiency of the Adcock antenna so that a compromise value of attenuation is used in practice. It has been found that an attenuation of 3 to 6 decibels is usually sufficient for this purpose.

The second important role played by the resistive means 20, 21 in the operation of the carrier-signal translating system concerns the impairment of the normally nondirective characteristic of the central antenna 17 by virtue of the close proximity thereto of the Adcock antenna 10. The nondirective characteristic of the antenna 17 is represented in Fig. 2 by curve *b*. Due to the proximity of the Adcock antenna 10 to the central antenna 17, the former incidentally picks up carrier-signal energy from the latter, mostly at the resonant frequencies of the Adcock antenna. Part of this energy is reradiated from the Adcock antenna 10 and causes undesirable and sometimes extreme irregularities in, or distortion of, the directive characteristic of the normally nondirective central antenna 17. The resistive means 20, 21 serves to reduce the magnitude of the en-

ergy which is picked up by the Adcock antenna 10 from the central antenna 17, and particularly in the vicinity of the odd-order natural resonant frequencies of the Adcock antenna, thus reducing also the magnitude of the reradiated energy whereby the impairment of the desired nondirective characteristic of the antenna 17, due to the close proximity thereto of the Adcock antenna 10, is materially reduced. This has the advantage that the directive properties of the antennas 10 and 17 can be combined to provide a directive characteristic for the signal-translating system which closely approximates a cardioid pattern, as represented by curve c of Fig. 3.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A directive antenna system comprising, an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission line in series and cross-connected at their junction, a balanced lead-in transmission line coupled to said two sections at the junction thereof, said antenna having a natural resonant frequency in the vicinity of the band of frequencies over which the system is to be operated, and means for reducing at predetermined operating frequencies the disturbing effect on the directive characteristic of said antenna of electrical unbalances of the components thereof with relation to the point at which said lead-in transmission line is coupled thereto comprising resistive means included in each of said transmission-line sections and having at least one effectively resistive element in the series paths of said sections which interconnect said pair of dipoles.

2. A directive antenna system comprising, an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission lines in series and cross-connected at their junction, a balanced lead-in transmission line coupled to said two sections at the junction thereof, said antenna having a natural resonant frequency in the vicinity of the band of frequencies over which the system is to be operated, and means for reducing at predetermined operating frequencies the disturbing effect on the directive characteristic of said antenna of electrical unbalances of the components thereof with relation to the point at which said lead-in transmission line is coupled thereto comprising resistive means included in each of said transmission-line sections adjacent the junction thereof and having at least one effectively resistive element in the series paths of said sections which interconnect said pair of dipoles.

3. A directive antenna system comprising, an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission line in series and cross-connected at their junction, a balanced lead-in transmission line coupled to said two sections at the junction thereof, said antenna having a natural resonant frequency in the vicinity of the band of frequencies over which the system is to be operated, and means for reducing to a minimum at predetermined operating frequencies the disturbing effect on the directive characteristic of said antenna of electrical unbalances of the components thereof with relation to the point at which said lead-in transmission line is coupled thereto comprising a balanced resistive attenuator network having at least one effectively resistive element serially included in each of said transmission-line sections.

4. A directive antenna system comprising, an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission line in series and cross-connected at their junction, a balanced lead-in transmission line coupled to said two sections at the junction thereof, said antenna having a natural resonant frequency in the vicinity of the band of frequencies over which the system is to be operated, and means for reducing to a minimum at predetermined operating frequencies the disturbing effect on the directive characteristic of said antenna of electrical unbalances of the components thereof with relation to the point at which said lead-in transmission line is coupled thereto comprising a balanced resistive attenuator network having at least one effectively resistive element serially included in each of said transmission-line sections adjacent the junction thereof.

5. A directive antenna system comprising, an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission line in series and cross-connected at their junction, a balanced lead-in transmission line coupled to said two sections at the junction thereof, said antenna having a natural resonant frequency in the vicinity of the band of frequencies over which the system is to be operated, and a resistive attenuator network included in each of said transmission-line sections adjacent the junction thereof, said networks being similar and having elements proportioned to match the impedance of said lead-in transmission line to said transmission-line sections and substantially to reduce at predetermined operating frequencies the disturbing effect on the directive character of said antenna of electrical unbalances of the components thereof with relation to the point at which said lead-in transmission line is coupled thereto.

6. A directive antenna system comprising, an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission line in series and cross-connected at their junction, a balanced lead-in transmission line coupled to said two sections at the junction thereof, a nondirective antenna centrally positioned with respect to said dipoles, a lead-in transmission line coupled to said nondirectional antenna, said Adcock antenna having natural resonant frequencies in the vicinity of the band of frequencies over which the system is to be operated, and means for reducing the pickup of carrier-signal energy by said Adcock antenna from said nondirectional antenna and the consequent reradiation of such energy in the vicinity of said resonant frequencies comprising resistive means included in each of said transmission-line sections.

7. A directive antenna system comprising, an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission line in series and cross-connected at their junction, a balanced lead-in transmission line coupled to said two sections at the junction thereof, a nondirective antenna cen-

trally positioned with respect to said dipoles, a lead-in transmission line coupled to said nondirective antenna, said Adcock antenna having natural resonant frequencies in the vicinity of the band of frequencies over which the system is to be operated, and means for reducing the pick-up of carrier-signal energy by said Adcock antenna from said nondirective antenna in the vicinity of said resonant frequencies comprising a balanced resistive attenuator network included in each of said transmission-line sections.

8. A directive antenna system comprising, an Adcock antenna including a pair of spaced parallel dipoles and two sections of interconnecting balanced transmission line in series and cross-connected at their junction, a balanced lead-in transmission line coupled to said two sections at the junction thereof, a nondirective antenna centrally positioned with respect to said dipoles, a lead-in transmission line coupled to said nondirective antenna, said Adcock antenna having natural resonant frequencies in the vicinity of the band of frequencies over which the system is to be operated, and means for reducing the pickup of carrier-signal energy by said Adcock antenna from said nondirective antenna and the consequent reradiation of such energy in the vicinity of odd-order natural resonant frequencies of said Adcock antenna comprising a resistor included in each of said transmission-line sections.

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