United States Patent

Lea

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[54] DIPOLE RADIO ANTENNAE

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[73] Assignee: **The Plessey Company Limited,** Ilford, England

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[21] Appl. No.: **879,753**

[52] **U.S. Cl.** **343/793,** 343/816, 343/822, 343/850, 343/853, 343/860

[51] **Int. Cl.** **H01g 9/16,** H01g 21/06

[58] **Field of Search** 343/793–798, 810–816, 343/799, 850–853, 845–849, 825–831, 700–703, 792

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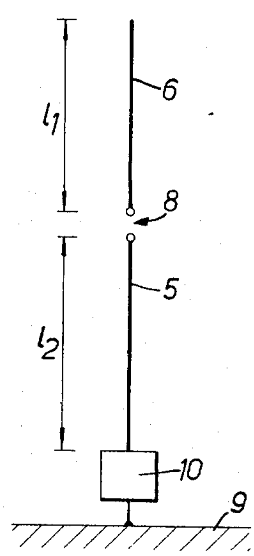
[57] **ABSTRACT**

Dipole whip antenna arrangements are disclosed which are capable of operating over a wide frequency band without the use of continual manual or automatic tuning. This is achieved by connecting the dipole whip antenna to the ground plane through a reactance network which is specially designed so as to match the impedance at the feed point of the dipole arrangement to a desired value over the desired frequency band. For this purpose, the reactance network is an active network, and operates by effectively cancelling out the reactance of the antenna.

2 Claims, 14 Drawing Figures



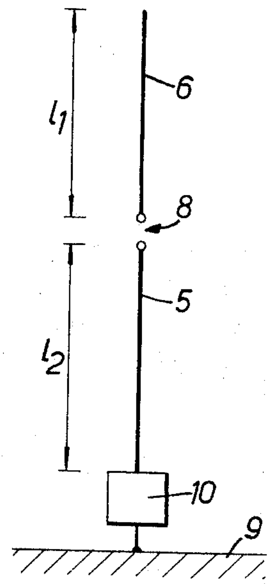


FIG. 1.

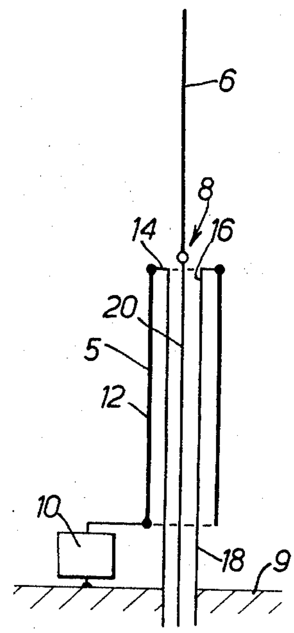


FIG. 2.

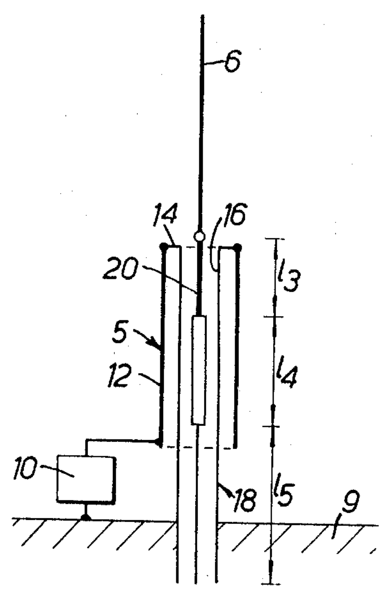


FIG. 3.

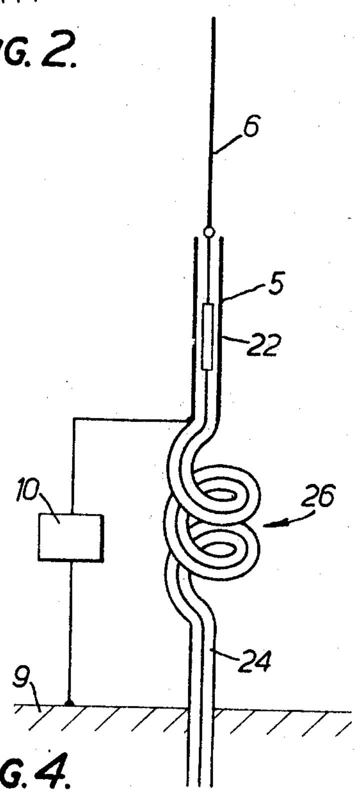


FIG. 4.

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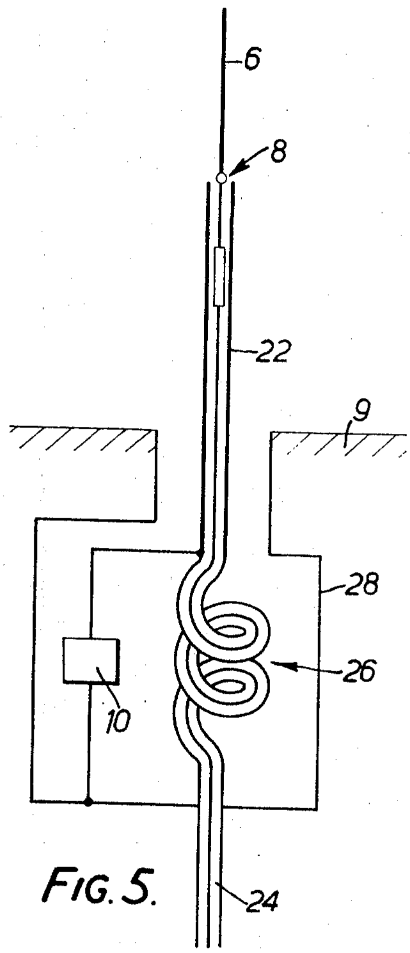

FIG. 5.

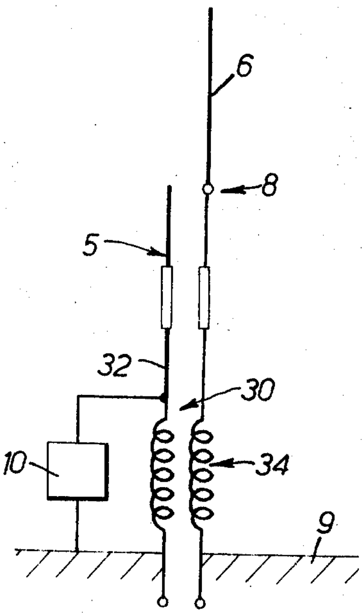

FIG. 6.

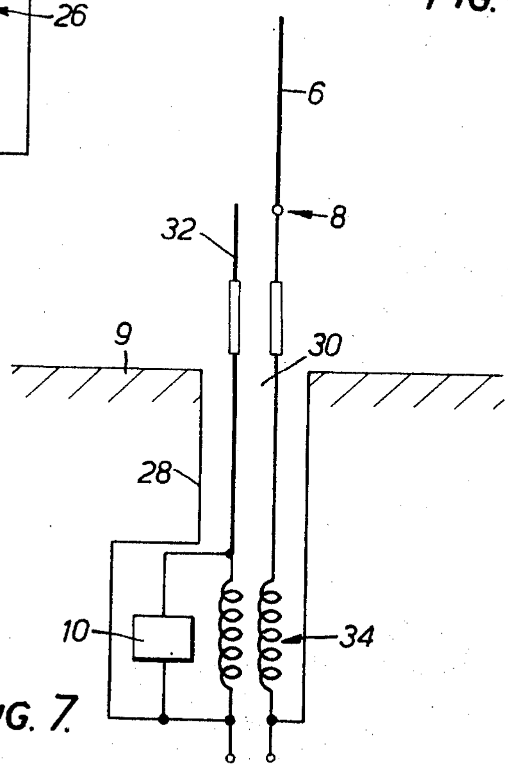

FIG. 7.

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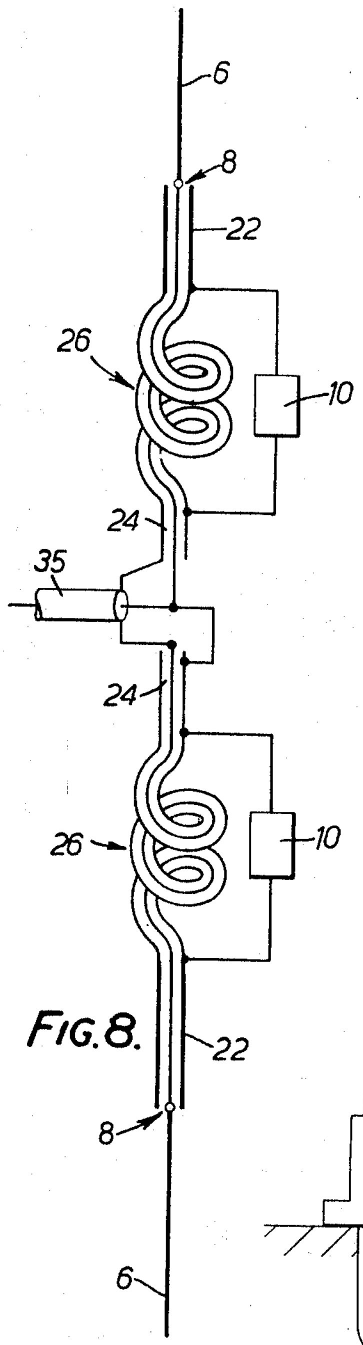

FIG. 8.

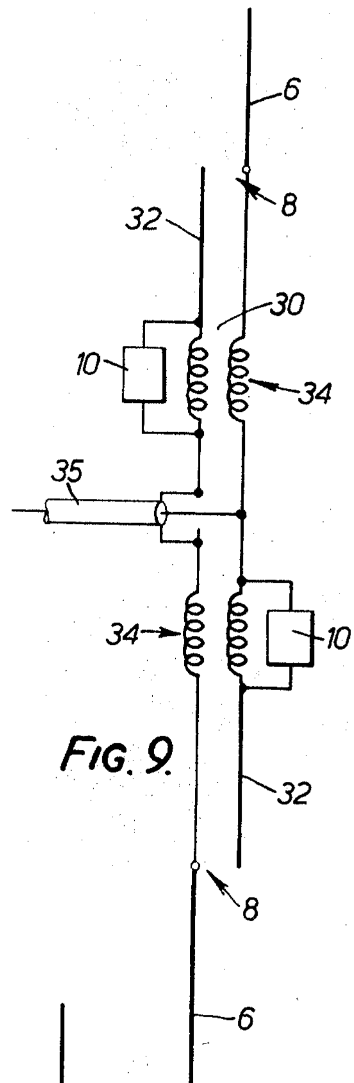

FIG. 9.

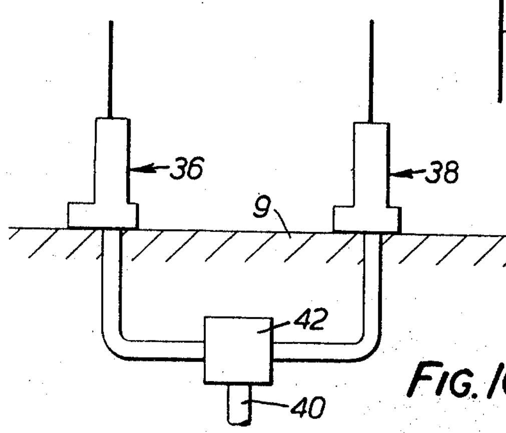

FIG. 10.

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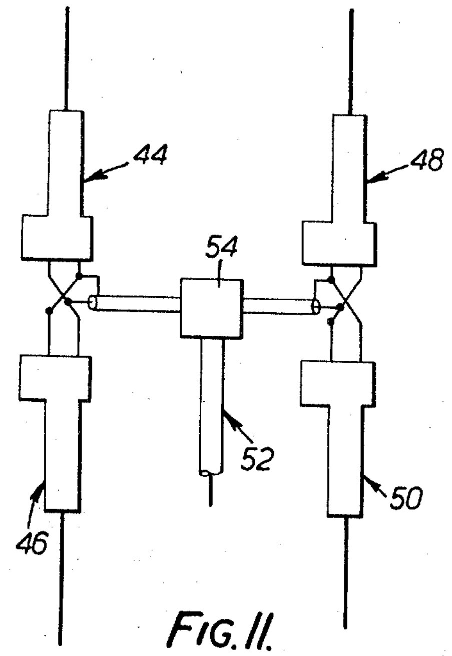

FIG. 11.

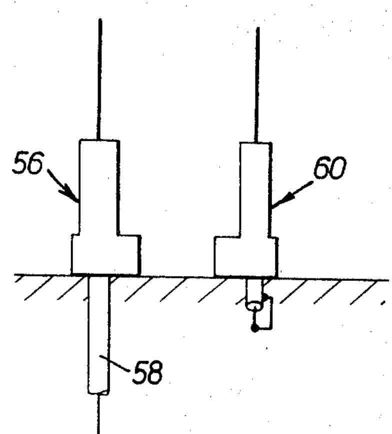

FIG. 12.

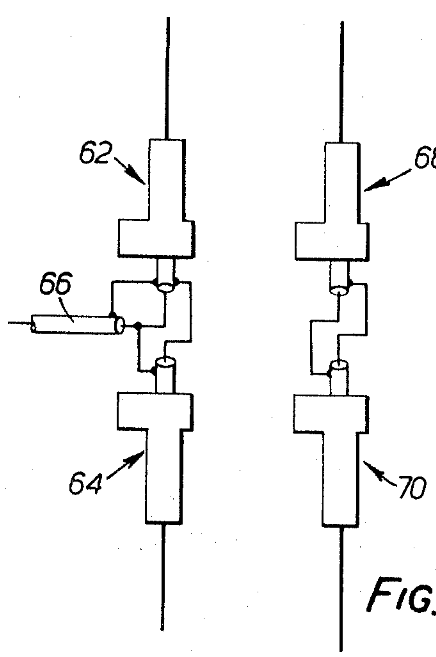

FIG. 13.

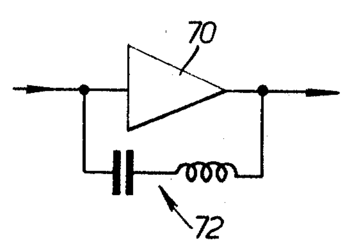

FIG. 14.

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DIPOLE RADIO ANTENNAE

BRIEF SUMMARY OF THE INVENTION

The invention relates to radio antennae, and is particularly though not exclusively, concerned with whip antennae.

The invention is concerned with the problem of providing a dipole antenna which can operate over a wide frequency band without the need for automatic or manual continuous tuning. A simple dipole antenna suffers from the disadvantage that it can only be used within a narrow frequency band. Outside the narrow frequency band for which it has been designed, a dipole antenna presents an unacceptable impedance to the equipment to which it is connected. In order to overcome this problem, it is known to provide a variable antenna tuning or matching unit which transforms the antenna impedance into a value which is acceptable to the equipment. Such a unit may be tuned manually by an operator, in which case this places demands on the operators's time and skill. Instead, the antenna tuning unit may be designed to set itself automatically, but this inevitably results in a large increase in cost and complexity and a corresponding reduction in reliability. Even with such an automatic antenna tuning unit, the antenna can only be used for a narrow band of frequency at any one time: it cannot be used for transmission or reception of wide band signals nor for transmission or reception of a number of widely spaced frequencies simultaneously.

Accordingly, the invention provides a dipole antenna arrangement comprising a dipole antenna having a reactance network connected in series with one element of the dipole, the reactance/frequency characteristic of the network being such as to match the impedance at the feed point of the dipole to a desired value over a wide frequency band.

The use of the reactance network, in accordance with the invention, thus enables the antenna arrangement to operate over a wide frequency band without the necessity for manual or automatic tuning, and in addition enables the antenna arrangement to be used for transmission or reception of wide band signals or of a plurality of widely spaced frequency simultaneously.

BRIEF DESCRIPTION OF THE DRAWINGS

Dipole whip antenna arrangements embodying the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIGS. 1 to 13 each show, diagrammatically, a different embodiment of the invention, the circuit connections of which are shown schematically; and

FIG. 14 is a schematic circuit diagram of a reactance network for use with the antenna arrangements.

An item in an Figure which corresponds to a similar item in any other Figure is given the same reference number.

DETAILED DESCRIPTION

In Figure **1**, the dipole whip antenna comprises two elements **5** and **6** having a feed point **8** by means of which the energy to be radiated can be fed in or by means of which radiation energy received by the antenna can be fed out, and the lower element **5** of the dipole is connected to a ground plane **9** through a two-terminal reactance network **10** having a reactance $X(f)$ which varies in a predetermined manner with frequency.

The impedance, Zf, at the feed point **8** depends on the lengths l_1 and l_2 of the two elements **5** and **6** of the dipole. The lengths l_1 and l_2 control Zf because they determine the way in which the amplitude and phase of the current flowing in the dipole varies along its length. The two-terminal reactance network **10** is so designed that the reactance at its terminals so varies with frequency that the impedance Zf maintains a desired value over a wide range of frequencies. In this way, the dipole whip antenna of FIG. **1** can be used over a wide frequency range without the need for a manually or automatically tunable antenna tuning unit, and the value of Zf is automatically maintained at a value which is acceptable to the equipment to which the antenna is to be connected. The antenna can thus be used for transmission or reception of any frequency over a wide range, or for transmission or reception of wide-band signals or simultaneously occurring signals having a number of widely spaced different frequencies.

FIG. **2** shows how a connection may be made to the feed point **8** from or to the associated equipment, not shown.

In FIG.**2**, the lower element **5** of the dipole whip antenna is formed by a hollow tube **12** which is electrically connected, at its upper end **14**, to the outer conductor **16** of a coaxial feeder **18** whose central conductor **20** connects to the upper element **6** of the antenna. The tube **12** is connected through the two-terminal reactance network **10** to the ground plane **9**. Therefore, the coaxial feeder **18** connects the feed point **8** of the dipole to the associated equipment, not shown.

In FIG.**2**, the annular space between the tube **12** and the outer conductor **16** of the coaxial feeder acts as a short-circuited length of transmission line and thus presents a reactance in parallel with the two-terminal network **10**. This parallel reactance is taken into account in designing the two-terminal network.

The impedance presented to the associated equipment, not shown, by the coaxial feeder **18** of FIG.**2** will not be equal to the feed point impedance Zf; the coaxial feeder, of characteristic impedance Zo, will transform the feed point impedance Zf to a new value, Z. By appropriately dimensioning the coaxial feeder **18**, so as to correspondingly to determine the characteristic impedance Zo, the impedance Zf can be transformed to Z in such a way as to provide a corresponding reduction in the effect, on the impedance Z, of variations in $Z(f)$ with frequency. Thus, the impedance transforming action of the coaxial feeder **18** augments the effect of the reactance **10** in increasing the operating band width of the antenna.

FIG.**3** shows an antenna in which the augmenting effect provided by the coaxial feeder **18** is further increased. The arrangement of FIG.**3** is generally similar to that of FIG.**2**, except that the diameter of the inner conductor **20** of the coaxial feeder is varied over its length. Thus, the diameter has one value over the length l_3 , another diameter over a length l_4 , and another diameter over a length l_5. In this way, the coaxial feeder acts as three impedance transformers connected in cascade thus further reducing the value of Z as compared with $Z(f)$ and thus further reducing variations in Z resulting from variations in $Z(f)$. In the embodiment of FIG.**4**, the outer conductor **22** of a coaxial feeder **24** itself forms the lower element **5** of the dipole whip antenna and, in a manner analogous to that shown in the previous Figures, is connected to the ground plane **9** through the reactance **10**. In order to prevent the coaxial feeder from short-circuiting the reactance **10**, the coaxial feeder itself is coiled up, over a region **26**, to form an inductor and thus provides r.f. isolation of the bottom of the dipole from the ground plane **9**. The inductance provided by the coil region **26** of the coaxial feeder, and its variation with frequencies, has to be taken into account in designing the reactance **10**. The coiled up region **26** of the coaxial feeder **24** of the embodiment of FIG.**4** does not effect the impedance-transforming action of the coaxial feeder which, as in the embodiment of Figures **2** and **3**, again augments the impedance matching effect of the reactance **10**; as in the case of FIG.**3**, this augmenting effect can be increased by varying the relative sizes of the two conductors of the feeder along its length.

FIG.**5** shows an arrangement corresponding to that of FIG.**4**, but the reactance network **10** and the coiled region **26** of the coaxial feeder **24** are enclosed in a screening tube **28** below and connected to the ground plane **9**. Such an arrangement can be used on vehicles and the like where it is desirable for physical protection purposes. The reactance presented at the bottom of the dipole by the network **10** and the inductive region **26** is transformed by the length of transmission line formed between the outer conductor **22** of the coaxial feeder and the screening tube **28**, and this has to be taken into account in designing the reactance network **10**.

In the embodiment of FIG.6, the external equipment is connected to the feed point **8** of the dipole whip antenna by means of a twin-wire or twin-strip transmission line **30**, one conductor **32** of which provides the lower element **5** of the dipole and the other of which is connected to the other element **6**. The conductor **32** of the transmission line **30** is connected to the ground plane **9** through the reactance **10**, and the bottom of the dipole is isolated, at radio frequencies, from the ground plane **9** by coiling up both conductors of the transmission line **30** over a region **34** to form a bifilar inductor. The operation is generally similar to that described in connection with the preceding Figures, and again the impedance matching effect of the reactance **10** is augmented by the impedance transforming effect of the transmission line **30**. In a manner analogous to that shown in FIG.3, the impedance transforming effect of the transmission line **30** of FIG.6 can be further increased by varying the sizes of the two conductors of the transmission line along their lengths as shown.

FIG.7 shows an embodiment analogous to that of FIG.5 in which the twin-wire transmission line **30** is arranged within a screening tube **28**.

FIGS. **8** and **9** show embodiments of the invention for use where no ground plane **9** is available (such as on the mast of a ship). FIG.8 corresponds to FIG.4 and consists of two dipole whip antennae arrangements, each as illustrated in FIG.4, which are combined to form a balanced pair. The coaxial feeders **24** of each of the two antennae of Fig. **8** are connected together to a common feeder **34** which is arranged to feed both antennae in phase so as to provide maximum radiation at right angles to the axis of the antennae.

FIG. **9** shows an arrangement analogous to FIG. **8** in which each of the two dipole whip antennae is an antenna as shown in FIG.6.

FIG.10 shows an embodiment of the invention providing a wide band directional array. It comprises two dipole whip antennae **36** and **38**, each of which is shown symbolically only but which may be of the form shown in FIGS. **1** to **7**. The two antennae **36** and **38** are spaced apart by a distance equal to one quarter of the wave-length at the mid band frequency. They are connected to be driven through a common feeder **40** which feeds through a phase shifting circuit **42** to provide a 90° phase difference between the signals supplied to each of the antenna.

FIG.11 shows a directional array comprising a first pair of balanced antennae **44** and **46**, and a second pair of balanced antennae **48** and **50**. The antennae **44** to **50** are shown symbolically only, but each is of the form shown in FIGS. **2**, **3**, **4** or **6**. The antennae are fed through a common feeder **52** and a phase shifting network **54**, the latter ensuring that there is a 90° phase difference between the signals supplied to the pair of antennae **44**, **46** and the signals supplied to the pair of antennae **48**, **50**.

Each of the arrangement of FIGS.10 and 11 may be modified by incorporating more than two antennae, or two pairs of antennae, in order to obtain higher directivity, and the phase shift between adjacent elements or adjacent pairs of elements may be made to change with frequency so as to maintain the directivity approximately constant over a wide frequency band.

Instead of the arrangements of Figs. **10** and **11**, a wide-band directional array can be constructed from a plurality of dipole whip antennae, each as disclosed herein, in which only one of the antennae is driven and the remainder parasitic. FIG.12 shows such an arrangement in which a dipole whip antenna **56**, which is shown only symbolically but which may take the form of an antenna as disclosed in one of the FIGS. **1** to **7**, is driven through a feeder **58**, while another dipole whip antenna **60**, which again may take the form of an antenna disclosed in one of the FIGS. **1** to **7**, is parasitic and has its feeder terminals short-circuited. FIG.13 shows an arrangement comprising a balanced pair of dipole whip antennae **62**, **64**, connected to be driven through a common feeder **66**, and a further pair of antennae **68**, **70** which are parasitic and which have their feeder terminals cross-connected. Each of the antennae **62**, **64**, **68**, **70** is shown symbolically only but may be as disclosed in any one of the FIGS. **2**, **3**, **4** and **6**.

It will be appreciated that each antenna shown symbolically in FIGS. **10** to **13** includes its respective network **10**.

In the arrangement of FIGS. **12** and **13**, the directivity of the array can be altered by adjusting the reactance/frequency characteristics of the two terminal reactance networks **10** associated with the parasitic elements of the arrays.

The method of designing the reactance network **10**, as used in the embodiments described, is first to calculate or measure the value of reactance required at each frequency. In one example of a centre-fed whip antenna with a bandwidth of approximately one octave, the reactance required is inductive at the lowest frequency. The reactance falls with increasing frequency, becoming zero, i.e. a short-circuit, at mid-band. At higher frequencies the reactance becomes capacitive and increases steadily up to the top frequency. This reactance variation is a mirror-image of the reactance of a series resonant circuit. Because it has a negative slope, it cannot be realised by a passive network. It can, however, be derived from a series-resonant circuit by means of an impedance converter. One example of impedance converter which can be used is shown in FIG. **14** and consists of a wide-band amplifier **70** with a voltage gain of +2, a high input impedance and a low output impedance. If an impedance Z is connected as a feed-back path between output and input, the input impedance is-Z.Thus, a suitable series resonant circuit **72** is connected as the feed-back path, so that the input impedance of the amplifier has the desired mirror-image reactance variation. The reactance network produced in this way may be said to produce the desired wide-band propoerty by cancelling out the reactance of the antenna. In order to do this it has to supply the reactive power associated with this reactance. Hence an active, or power-conversion device is necessary.

It will be appreciated that many modifications may be made to the embodiments described without departing from the scope of the invention. As an example, it may be noted that the arrangement of FIG. **1** may be modified by connecting the reactance network **10** to the feed point **8**, and feeding the antenna between the bottom end of the element **5** and the ground plane.

Although the specific embodiments described are all whip antennae, the invention is not limited to whip antennae.

What is claimed is:

1. A dipole antenna arrangement, comprising
   - a dipole antenna having two antenna elements and a feedpoint,
   - a reactance network comprising a wide-band amplifier constituting an active impedance-converting device, a series resonant circuit, and means connecting the series resonant circuit to provide a negative feed-back path across the amplifier, and
   - means connecting the reactance network in circuit with one element of the dipole,
   - the gain of the amplifier and the impedance of the resonant circuit being so chosen that the effective overall input impedance of the amplifier varies with frequency to give the network a reactance/frequency characteristic such as to match the impedance at the feedpoint of the dipole to a desired value over a wide frequency range.

2. An antenna arrangement according to claim **1**, comprising
   - a further dipole antenna having two antenna elements and a feedpoint,
   - a further reactance network comprising a wide-band amplifier constituting an active impedance-converting device, a series resonant circuit, and means connecting the series resonant circuit to provide a negative feedback path across the amplifier,
   - means connecting the further reactance network in series with one element of the further dipole,

the gain of the amplifier and the impedance of the resonant circuit being so chosen that the effective overall input impedance of the amplifier varies with frequency to give the further network a reactance/frequency characteristic such as to match the impedance at the feedpoint of the further dipole to a desired value over a wide frequency range.

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