

Oct. 13, 1970

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3,534,371

PLURAL DIPOLE VERTICAL ANTENNA WITH ISOLATION CHOKES

Filed July 10, 1968

3 Sheets-Sheet 1

FIG. 1

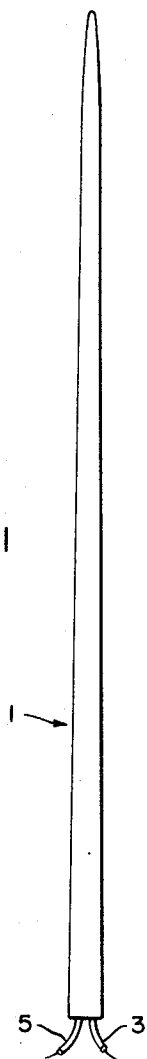


FIG. 2

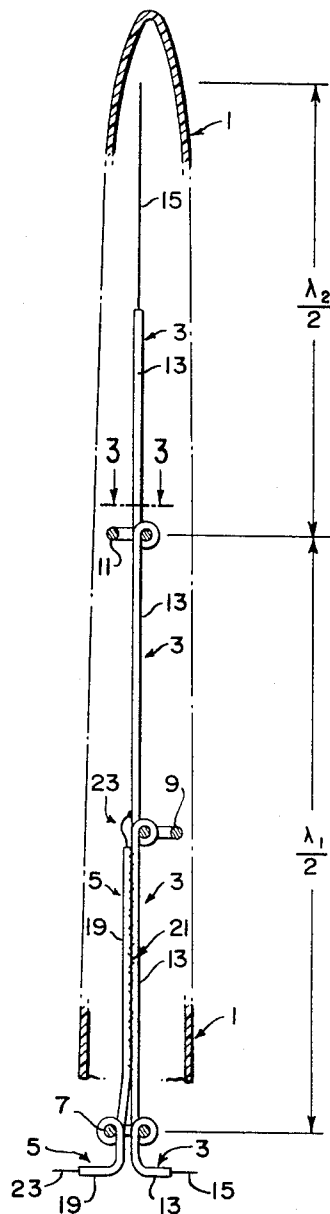


FIG. 3

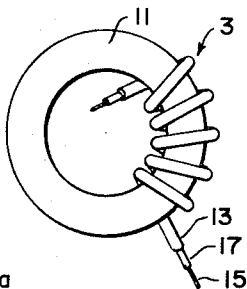
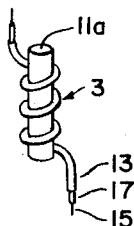


FIG. 4



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FIG. 5A

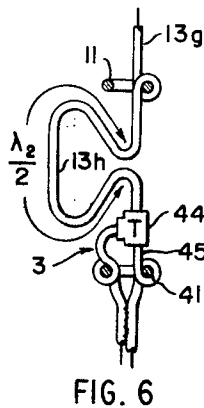
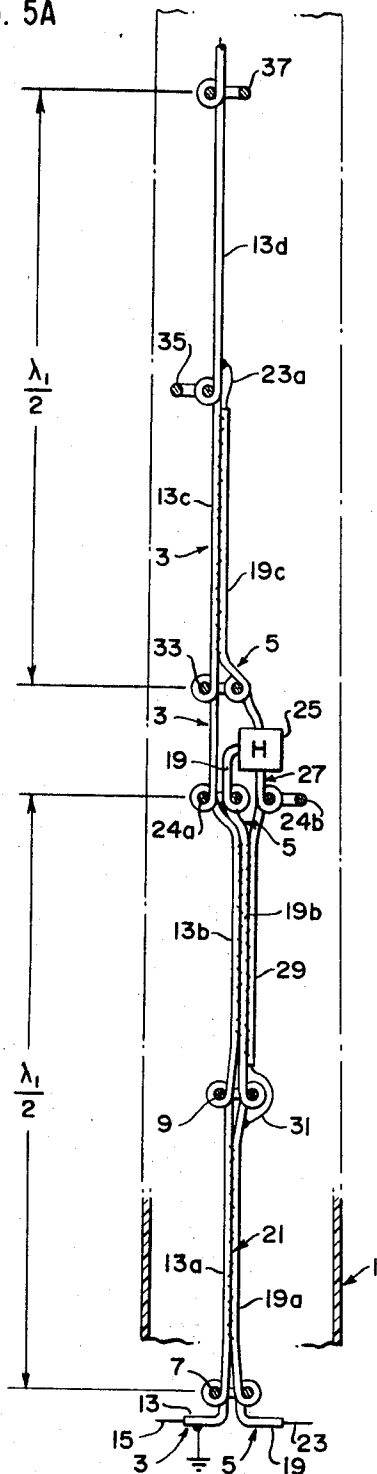
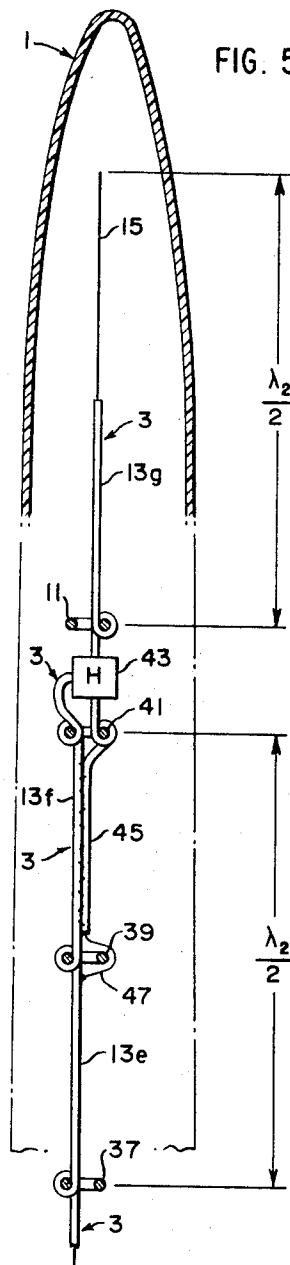


FIG. 5B



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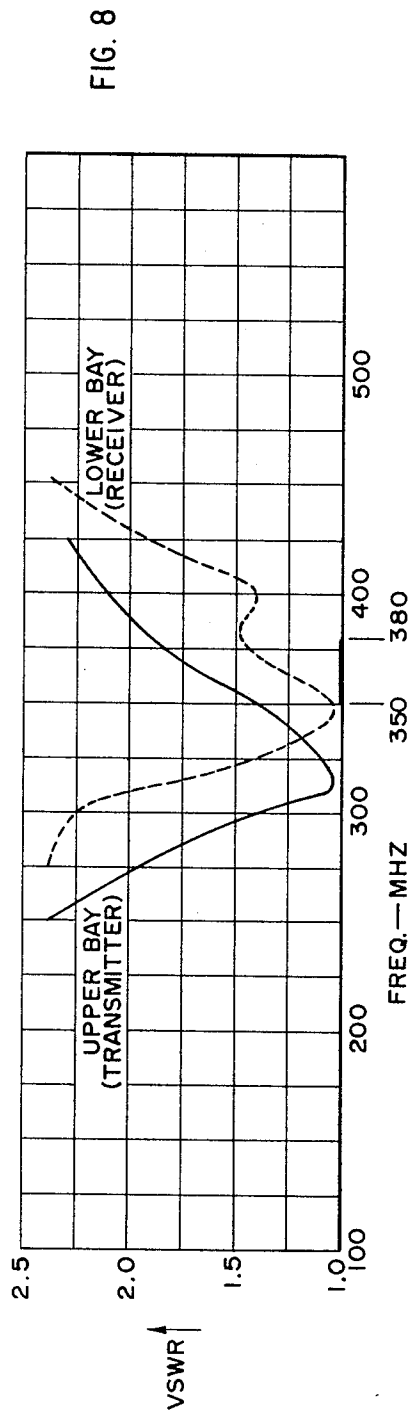
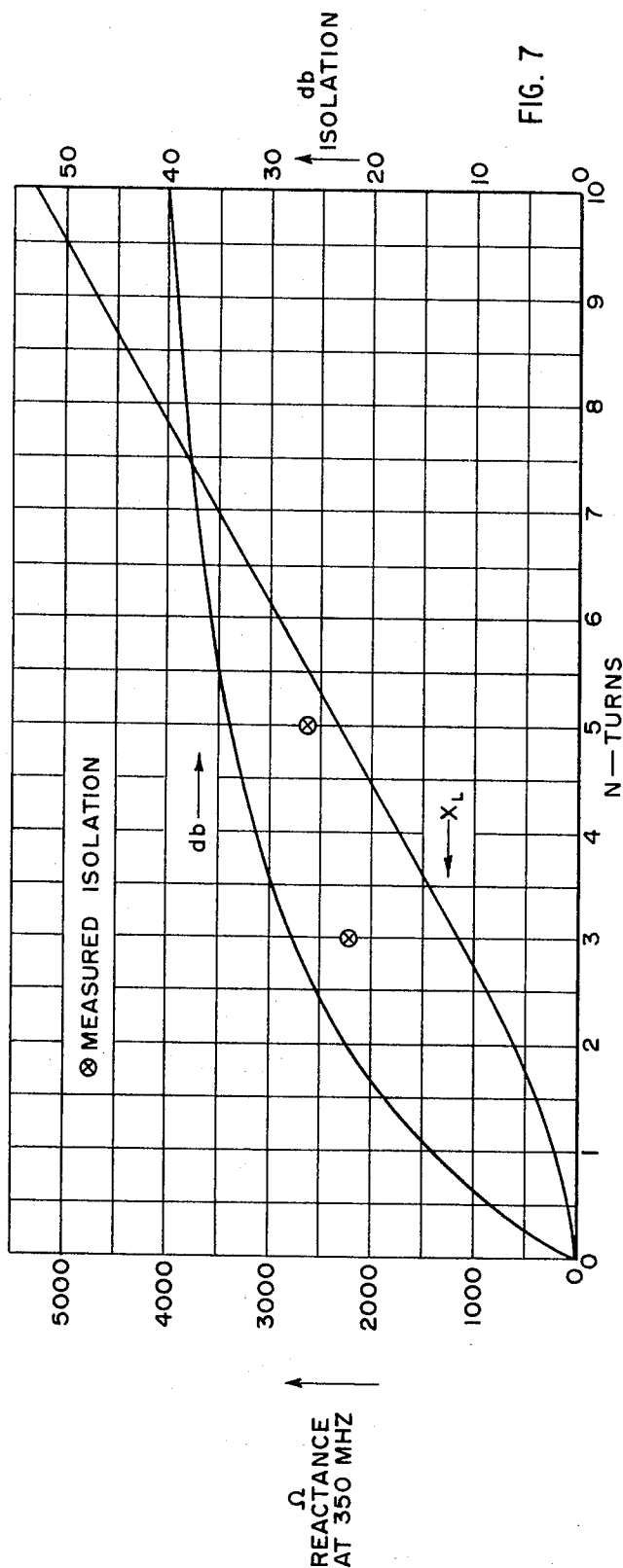
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PLURAL DIPOLE VERTICAL ANTENNA WITH ISOLATION CHOKES

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3 Sheets-Sheet 3



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PLURAL DIPOLE VERTICAL ANTENNA WITH ISOLATION CHOKES

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Filed July 10, 1968, Ser. No. 743,797

Int. Cl. H01q 1/00, 9/16

U.S. Cl. 343—722

9 Claims

ABSTRACT OF THE DISCLOSURE

A flexible multiple element linear array antenna using ferrite core chokes for control of mast currents and inter-element isolation.

My invention relates to antenna construction, and particularly to a novel, flexible, multi-element linear array antenna.

Particularly for use in mobile, high gain UHF transmission and reception, an antenna which is flexible, light in weight and of precisely controllable radiation characteristics is highly desirable. Construction of suitable single radiator, single frequency antennas for this purpose presents no problem in the present state of the art. However, where a multiple element array, in which the elements operate either at the same or at different frequencies, is needed, conventional constructions tend to be complex, cumbersome, fragile and expensive. It is the object of my invention to facilitate the construction of flexible, vertically polarized multi-element linear array antennas of light weight and controllable radiation characteristics.

Briefly, the above and other objects of my invention are attained by a novel whip antenna construction in which the outer element is a supporting mast of non-conducting, relatively flexible and yet strong material, such as tubing of epoxy resin filled with glass fibers, or the like. Within this tubing are lodged the electrical components of the antenna of my invention. These elements comprise primarily one or more relatively flexible coaxial cables, and a set of ferrite cores. The coaxial cable forms an upper or outer dipole comprising as one half the outer conducting sheathing of the coaxial cable, and as the other half the inner conductor of the coaxial cable, extending into the upper end of the mast. The inner conductor may either protrude linearly for the appropriate distance from the outer conductor to form the second element of the dipole, or may be connected to any conventional radiator to serve the same purpose.

In accordance with my invention, the outer dipole is mechanically connected to, but electrically isolated from, a second dipole lower in the mast. Isolation is attained by winding the coaxial cable one or more times about a ferrite core. The cable then runs down the mast to a second ferrite core. It is also wound one or more times about the second core, and then runs down the mast to a third ferrite core. The cable is wound one or more times about the third core, and is then led to the receiving or transmitting circuits.

So far as the inner feed circuit for the outer dipole is concerned, the ferrite cores have no effect. However with respect to the sections of conducting outer sheathing, the wound cores act as radio frequency chokes. Thus, the two sheathing sections, one extending from the upper core to

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the center core, and the other extending from the center to the lower core, act as the independent sections of a second dipole, one of which may be excited with respect to the other by means to be described. The result is a simple and effective arrangement by which two independent dipoles can be arranged in a thin and flexible insulating mast and can be operated at the same or different frequencies with substantial electrical isolation between the two dipoles.

The manner in which the apparatus of my invention is constructed, and its mode of operation, will best be understood in the light of the following detailed description, together with the accompanying drawings, of various practical embodiments.

In the drawings:

FIG. 1 is an elevational sketch showing the outer appearance of an antenna in accordance with my invention;

FIG. 2 is a schematic elevational view, with parts shown in cross section and parts broken away, of an antenna in accordance with a first embodiment of my invention;

FIG. 3 is a schematic plan view of a toroidal choke forming a part of the apparatus of FIG. 2, and also suitable for use in other embodiments to be described;

FIG. 4 is a schematic plan of a cylindrical choke which, in certain embodiments, has size and fabrication advantages.

FIGS. 5A and 5B comprise schematic elevational views, with parts shown in cross section and parts broken away, of the top and bottom portions, respectively, of an antenna in accordance with a second embodiment of my invention;

FIG. 6 is a schematic view, with parts shown in cross-section and parts broken away, of a modification of the apparatus of FIG. 5B;

FIG. 7 is a composite graph of the isolation and reactance characteristics of the chokes of FIGS. 3 and 4; and

FIG. 8 is a graph illustrating the measured performance characteristics of the antenna of FIGS. 5A and 5B under typical operating conditions.

FIG. 1 shows the typical external proportions of a completed antenna construction in accordance with my invention. Generally, the antenna comprises an outer flexible mast portion 1 of glass fiber filled epoxy resin or the like. A pair of coaxial cables, generally designated as 3 and 5, protrude from the bottom of the mast 1. The lower portion of the mast may be fitted with any suitable conventional mounting and connector assembly, not shown, as will be apparent to those skilled in the art without further description.

It is apparent that it would be difficult, if not impossible, to show the internal construction of the antenna while maintaining the proportions of FIG. 1. Accordingly, in FIGS. 2-4 of the drawings, the physical proportions and locations of the parts have been somewhat distorted in order to make the electrical aspects of the apparatus clear. More particularly, the lengths of the radiating elements are relatively shorter with respect to the size of the cores than would normally be the case in practice, and the diameter of the outer mast is shown considerably larger in proportion to its length than would normally be necessary.

FIG. 2 shows the construction of one embodiment of the antenna of FIG. 1 in more detail. The construction, and the relative proportions of the parts, may be more readily comprehended if it is mentioned that a typical dimension for the cables 3 and 5 is one-sixteenth of an inch in outer

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diameter. Of course, that dimension is merely illustrative and is not in any sense critical.

As shown in FIG. 2, there are located in the insulating mast three spaced ferrite cores 7, 9 and 11. The cores 7 and 11 are spaced apart essentially a distance $\lambda_1/2$, where λ_1 is a desired operating wavelength. The core 9 is equally spaced from the cores 7 and 11.

The coaxial cables 3 and 5 are each wound one or more times about the core 7. When a cylindrical core is used, a standard bifilar winding geometry is employed. In practice, as a typical example, five turns would be appropriate for operation at 350 mHz. For use with coaxial cables of the diameter mentioned above, toroid cores such as 7 could be ferrite toroids $\frac{1}{2}$ inch in diameter and $\frac{1}{4}$ inch high.

The cable 3 extends upward to the core 9, about which it also is wound. The cable 3 then extends upwardly and is again wound about the core 11.

From the core 11, the outer conducting sheathing 13 of the cable extends upwardly a distance $\lambda_2/4$, where λ_2 may be the same as, or different from, λ_1 . The inner conductor 15 of the cable protrudes upwardly from the termination of the outer conductor 13 by a distance $\lambda_2/4$.

The manner in which the cables such as 3 and 5 are wound on the cores is more clearly shown in FIG. 3, illustrating the manner in which cable 3 is wound on the core 11. As also shown in FIG. 3, a conventional dielectric insulator 17 (part of the coaxial cable) separates the conductors 13 and 15.

FIG. 4 shows an alternate form of core 11a that may be used to advantage where the physical size of the apparatus, the number of turns required by the operating frequency, or other considerations make it more convenient. The forms of choke shown in FIGS. 3 and 4 have been formed to have the same electrical characteristics, and either can be used in any of the apparatus herein described.

The second coaxial cable 5 is also wound on the core 7. Alternatively, it could be wound on a separate core in approximately the same location, if that construction proved more convenient. Above the core 7, the outer conductor 19 of the cable 5 extends along the cable 3 essentially to the core 9, and in this region between the cores 7 and 9 the outer conductors 13 and 19 may be soldered together as suggested at 21. The inner conductor 23 of the cable 5 is soldered to the outer conductor 13 of the cable 3 above the choke formed by the winding on the core 9.

The chokes formed by the windings on the cores 7, 9 and 11 are not electrically effective in the RF circuit including the conductors 13 and 15. However, the choke 11 serves to electrically insulate the portion of the outer conductor 13 above it from the portion below it. The result is that if, for example, the lead 15 is excited with respect to the conductor 13 at the bottom of the mast 1 with a voltage at the wavelength λ_2 , the portion of the cable 3 above the choke 11 will radiate at λ_2 as a dipole electrically isolated from the lower portion of the antenna.

In a similar manner, the choke 9 serves to isolate the portion of the outer conductor 13 above it from the portion below it, so that when lead 23 is excited with respect to the outer conductor 19 with a voltage at the wavelength λ_1 , a portion of the antenna between the chokes 7 and 11 will radiate as a dipole at the wavelength λ_1 . The choke comprising the core 7 serves both to resonate the lower dipole and to suppress mast currents.

FIGS. 5A and 5B show a double bay antenna, with double elements in each bay, constructed in accordance with a modified embodiment of my invention. As an aid in comparing the construction of FIGS. 5A and 5B with that of FIG. 2, basic corresponding elements have been given corresponding reference numerals. Thus, the coaxial cable feeding the upper radiating elements has been designated 3, the cable feeding the lower elements has been designated 5, and the outer insulating mast is designated 1.

In the embodiment of FIG. 5A, the core 7 serves the same purposes as in the construction of FIG. 1. The outer

conductors 13a and 19a of the cables 3 and 5, respectively, are soldered together, as at 21, above the core 7 to form the lower element of a first dipole of length $\lambda_1/2$. The conductor segments 13a and 19a are electrically isolated from portions 13b and 19b, comprising the second element of the same dipole, by windings of the cables 3 and 5 about a ferrite core 9, which performs the same functions as the core 9 in FIG. 2.

The dipole element comprising the conductor sections 13b and 19b is terminated at the top by chokes formed by winding cable 3 about a ferrite core 24a and winding cable 5 about a core 24b. These cores could comprise a single core, but are shown separately for clarity of illustration.

The cable 5 is connected to the difference port of a conventional hybrid junction 25 connected as a difference T to divide power supplied to the difference port between two collateral ports. One collateral port of the junction 25 is connected to a coaxial cable 27. The cable 27 is first isolated by winding it about a ferrite core, here shown as the core 24b. It is then laid down along the cables 13b and 19b and the outer conductor 29 of the cable 27 is soldered to the conductor portions 13b and 19b. At the lower end, the inner conductor 31 of the cable 27 is electrically connected to the outer conductor portions 13a and 19a below the core 9.

It will be apparent that by the construction so far described, a lower dipole of length $\lambda_1/2$ is formed that may be fed by exciting the conductor 23 with respect to the conductor 19. An upper dipole of length $\lambda_1/2$ is formed above the lower dipole to complete the lower bay, in a manner next to be described.

A core 33 is positioned just above the hybrid T 25. The second collateral port of the junction 25 is connected to an extension of the cable 5. That extension is first isolated by winding about the core 33, and then passes up along an outer conducting portion 13c of the cable 3. The outer conductor 19c of the cable 5 is soldered to the outer conductor 13c, and the extension 23a of the inner conductor 23 is connected to a portion 13d of the outer conductor of the cable 3.

Portions 13c and 13d are isolated from each other by winding the cable 3 on a core 35. The upper portion 13d of the second dipole is terminated by winding the cable 3 on a core 37. That serves both to resonate the second dipole and to isolate the lower bay of the antenna, comprising the apparatus just described, from the upper bay, next to be described.

FIG. 5B shows the upper portion of the antenna, including the isolating choke 37 also shown in FIG. 5A. A lower dipole of the upper array is formed by sections 13e and 13f of the outer conductor of the cable 3 isolated from each other by windings of the cable 3 on a core 39. The upper dipole element 13f is terminated by winding the cable 3 on a core 41. The lengths of 13e and 13f are each $\lambda_2/4$, where λ_2 may be the same as, or different from, λ_1 .

Above the core 41, the cable 3 is coupled to the difference port of a second hybrid junction 43. One collateral port of the junction 43 is connected to a coaxial cable segment 45. The cable segment 45 is isolated by winding about the core 41, and then extended along the conductor segment 13f. The outer conductor of the cable 45 is soldered to the conductor portion 13f. The inner conductor 47 of the cable segment 45 is electrically connected to the conductor segment 13e below the core 39.

The second collateral port of the hybrid junction 43 is connected to the end of the cable 3, which is wound about the core 11 and arranged to produce the terminal dipole exactly as described in connection with FIG. 2. It will be apparent that the upper pair of dipoles may be excited at the wavelength λ_2 by feeding at the bottom of the mast, using the conductors 13 and 15.

FIG. 6 shows a modification of the apparatus of FIG. 5B in which a conventional coaxial line T, rather than a

hybrid junction, is employed. The T 44 is connected in the circuit in the same manner as the junction 43. However, since the voltages at the terminals of the coaxial T are in phase, whereas those at the collateral points of the junction are 180° out of phase, a phase correction is needed. As shown in FIG. 6, the necessary phase correction may be made by including an additional cable segment 13b, of length $\lambda_1/2$ between the T 44 and the core 11. Alternatively, if desired, the added length could be included in the cable 45 between the T 44 and the core 41, rather than in the cable 13. The additional length, such as 13h, can be packaged in the supporting mast 1 by folding it, or winding it into a coil. If desired, the same arrangement could also be used in place of the hybrid junction 25 in FIG. 5A.

FIG. 7 shows typical reactance and isolation characteristics obtainable with $1/16$ inch coaxial cable at 350 MHz., with Q2 ferrites $1/2$ inch in diameter and $1/4$ inch in height, as a function of the number of turns of the cable about the core.

FIG. 8 shows typical performance characteristics of an array of the type shown in FIGS. 5A and 5B. The performance characteristics are shown in terms of the voltage standing wave ratio (VSWR) as a function of frequency when the upper bay is used as a transmitter and the lower bay is used as a receiver.

The antenna construction of my invention can be extended to include any desired number of dipoles of the same or different frequencies in the same mast. As illustrated in FIGS. 5A and 5B, where a cable such as B is used to feed a dipole higher on the mast, any lower dipoles on the mast are bypassed by soldering the outer conductor of the cable such as 3 to the outer conductors of the lower cables such as 5 along each of the dipole elements to be bypassed. Thus, for example, a fifth dipole operating at a wavelength λ_3 could be added below the lower dipole in FIG. 5A, using a third coaxial cable. The outer conductors 13 and 19 would be soldered together and to the outer elements of that fifth dipole formed by the outer conductor of the third cable, below the core 7. More complex extensions of the same construction will be obvious to those skilled in the art from the examples given.

While I have described my invention with respect to the details of various embodiments thereof, many changes and variations will be apparent to those skilled in the art upon reading my description, and such can obviously be made without departing from the scope of my invention.

Having thus described my invention, what I claim is:

1. In an antenna, a length of coaxial cable comprising an outer conductor and an inner conductor, first, second and third linearly spaced ferromagnetic cores at intervals $\lambda_1/4$, said cable being wound at least once about said first core, extending to and being wound at least once about said second core, extending to and being wound at least once about said third core, and protruding linearly from said third core to a termination at a distance $\lambda_2/4$, and said inner conductor protruding from said termination a distance $\lambda_2/4$, whereby two electrically independent dipoles of lengths $\lambda_1/2$ and $\lambda_2/2$ are formed.

2. An antenna, comprising a flexible tubular non-conducting mast, three ferromagnetic cores mounted in linear spaced relation in said mast, a first of said cores being located at least a distance

$$\lambda_1 + \lambda_2/2$$

from a first end of said mast, a second of said cores being located closer to said first end than said first core and spaced from said first core about a distance $\lambda_1/4$, said third core being located closer to said first end than said second core and spaced about $\lambda_1/4$ from said second core, a coaxial cable comprising an inner conductor and an outer conductor, said cable extending into said mast from a second end opposite said first end, being wound about said first core at least once, extending to and wound about

said second core at least once, extending to and wound about said third core and protruding from said third core toward the end of said mast, said outer conductor protruding a distance $\lambda_2/4$ from said third core, and said inner conductor protruding a distance $\lambda_2/2$ from said third core, and means for exciting the portion of said outer conductor between said first and second cores with respect to the portion of said outer conductor between said second and third cores with an alternating voltage having a wavelength λ_1 .

3. The apparatus of claim 2, in which said last recited means comprises a second coaxial cable extending into said mast at said second end, being wound at least once about said first core, having an outer conductor extending along the outer conductor of said first recited cable between said first and second cores and being electrically connected thereto, and having an inner conductor extending through the outer conductor and being electrically connected to the outer conductor of said first recited cable adjacent said second core and between said second and third cores.

4. In an antenna, a multiple element array comprising a length of coaxial cable having an inner and an outer conductor, first, second and third ferromagnetic cores, said cable being wound at least once about each of said cores and comprising a first length extending between said first core and said second core, a second equal length extending between said second and said third cores, and a portion extending from said third core for a predetermined length, and an electrical extension of said inner conductor equal to said predetermined length.

5. An antenna comprising a linear array of dipoles formed from a length of coaxial cable, in which a terminal dipole is formed by the outer conductor of said length of coaxial cable and by an electrical extension of the same length of the inner conductor and at least one other dipole is formed by equal adjacent lengths of the outer conductor of said cable, and in which the several elements of the antenna formed by adjacent lengths of the outer conductor of the cable are electrically isolated by portions of the cable wound about ferrite cores.

6. The antenna of claim 5, in which said cable is of flexible material, the antenna comprising said cable and cores being mounted in a flexible tubular supporting mast of insulating material.

7. In an antenna, a two element bay comprising first, second, third and fourth linearly spaced ferromagnetic cores, said second core being essentially a distance $\lambda_1/4$ from said first core, said third core being essentially a distance $\lambda_1/4$ from said second core and essentially a distance $\lambda_1/2$ from said first core, said fourth core being disposed adjacent said third core and beyond said third core in the direction from said first core toward said second core, a first coaxial cable having an inner conductor and an outer conductor, said first cable being wound at least once about said first core, extending to and wound at least once about said second core, and extending to and wound at least once about said third core, a second coaxial cable having an inner conductor and an outer conductor, said second cable being wound at least once about said fourth core and protruding linearly from said fourth core in the direction from said first core toward said second core, the outer conductor of said second cable protruding a distance $\lambda_1/4$ from said fourth core, means comprising an electrical extension of the inner conductor protruding a distance $\lambda_1/2$ from said fourth core, a third coaxial cable having an inner conductor and an outer conductor, said third cable being wound at least once about said third core, the outer conductor of said third cable extending along and being conductively connected to the outer conductor of said first cable between said second and third cores, the inner conductor of said third cable being connected to the outer conductor of said first cable adjacent said second core and between said first and second cores, and a power divider connecting said first cable

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to said second and third cables between said third and fourth cores.

8. The apparatus of claim 7, in which said power divider comprises a coaxial line T, and in which one of said second and third cables includes a length $\lambda_1/2$ between the power divider and the nearest end of its associated dipole. 5

9. The apparatus of claim 7, in which said power divider comprises a hybrid junction having a difference port connected to said first cable, a first collateral port connected to said second cable, and a second collateral port 10 connected to said third cable.

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U.S. Cl. X.R.

343—787, 792, 853, 872