ANTENNA WITH PATTERN DIRECTIVITY CONTROL

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FIG. 1

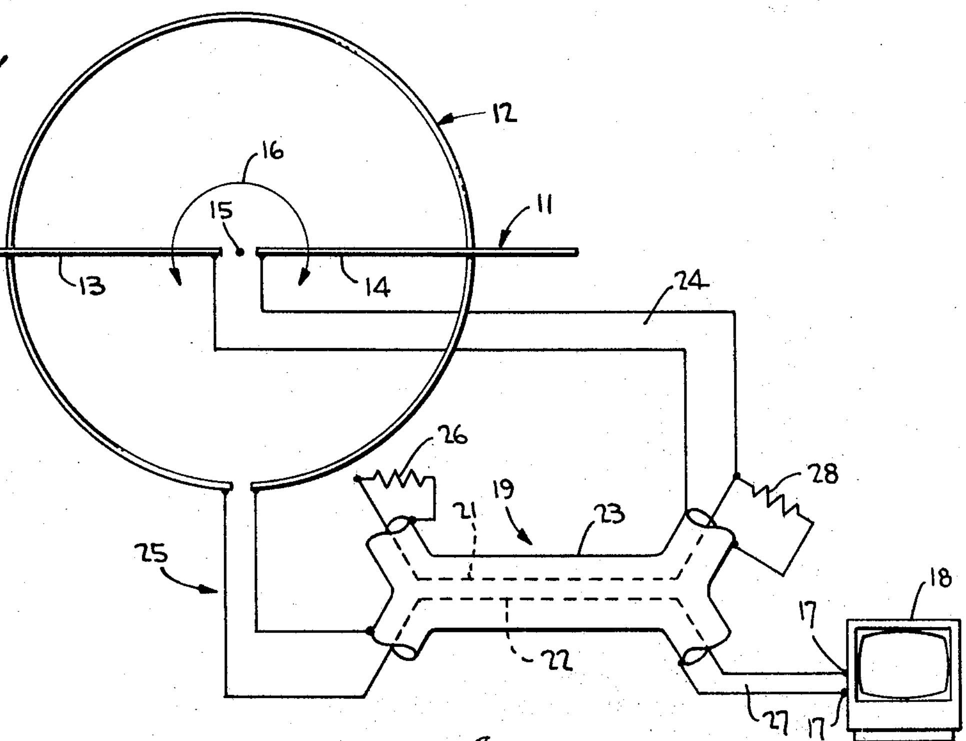
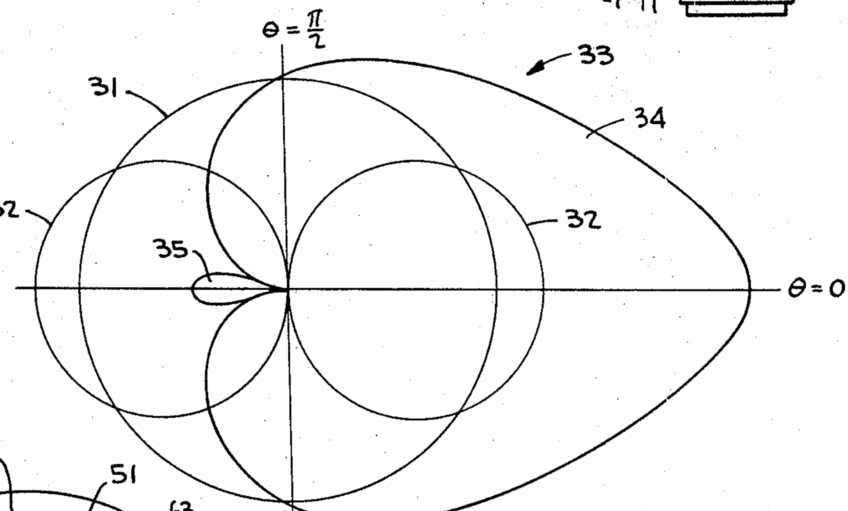


FIG. 2



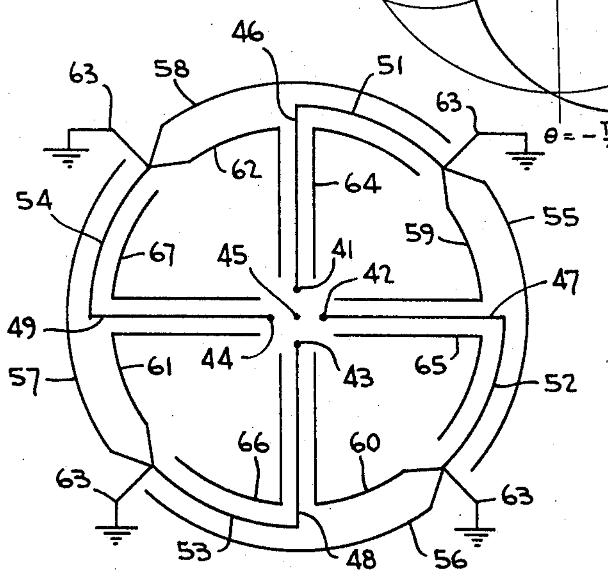


FIG. 3

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FIG. 4

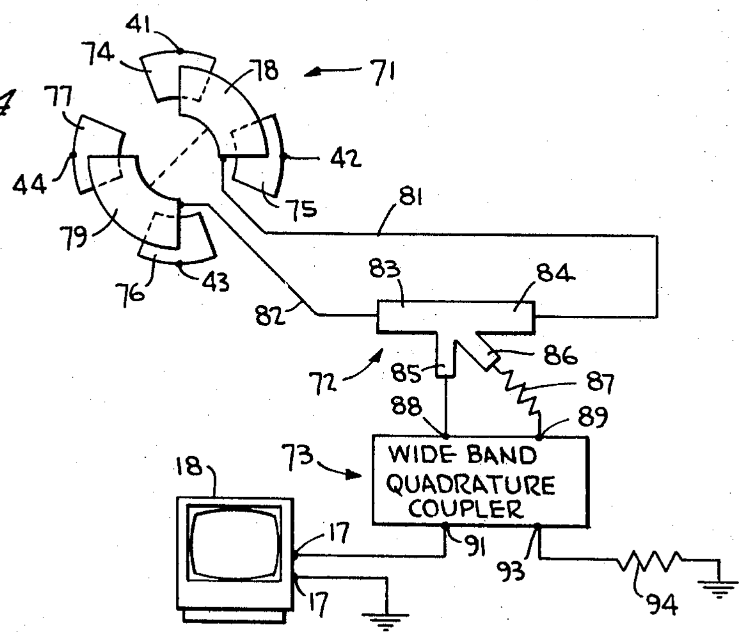
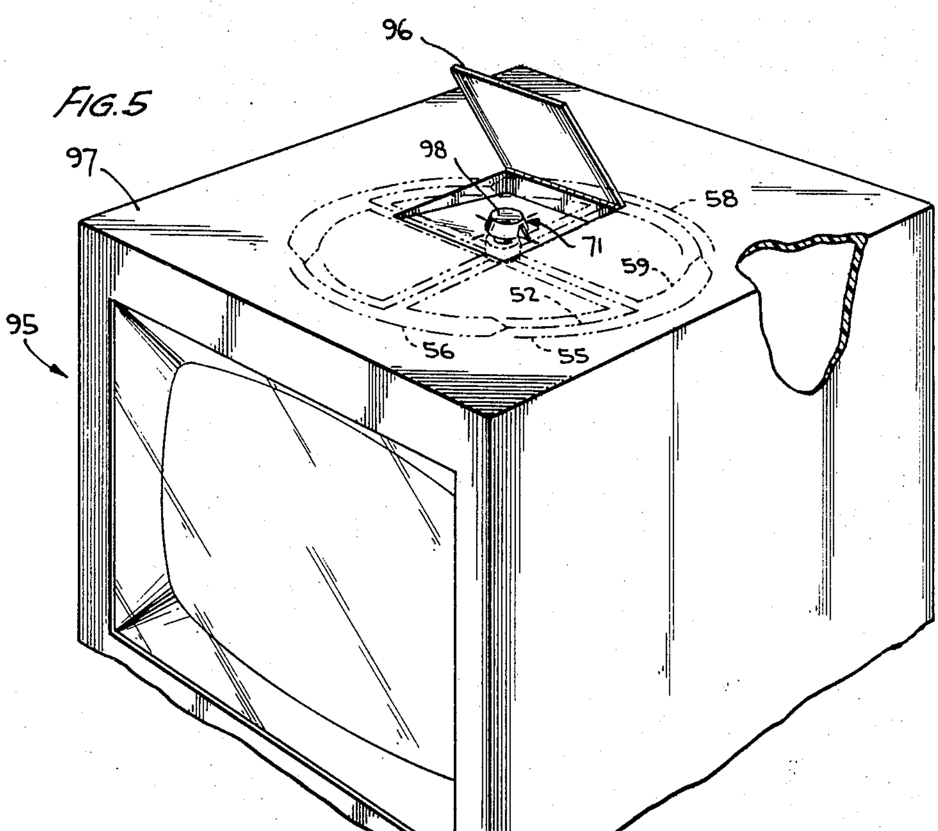


FIG. 5



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ANTENNA WITH PATTERN DIRECTIVITY CONTROL

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ABSTRACT OF THE DISCLOSURE

A wide band antenna array, for minimizing the effect of multi-path radiation on a television image, has an omnidirectional, loop-like pattern and a dipole-like pattern. The array is excited so the separate patterns produce a resultant pattern having a broad, substantial null behind a main lobe and a constant frequency response over the VHF television band for both patterns.

The present invention relates generally to wave energy transducers and, more particularly, to a wave energy transducing array wherein an omnidirectional radiation pattern is combined with a pattern including a plurality of nulls.

A prime requisite of transducers for converting television electromagnetic waves, in strong signal areas, to electric signals, i.e., television antennas, is elimination of reflected or multi-path energy impinging on the transducer. In regions of strong television signal strength wherein field strengths exceed 5,000 microvolts per meter, such as business or densely populated areas of a city, multiple reflections from tall buildings and other structures frequently result in ghost images on a television receiver screen.

To eliminate ghost images from the screen of a television receiver, television receiving antennas adapted to be utilized in strong signal areas should generally be designed so that the pattern thereof has one relatively narrow main lobe and substantially no side or back lobes. In many instances, the substantial elimination of a back lobe is as important as the elimination of side lobes because energy forming ghost images is generally defined by a family of confocal ellipses with foci at the transmitting and receiving antennas. Each ellipse represents the locus of ghost forming objects which will produce a given separation between image and ghost. Hence, the apparent source of reflections from objects located behind the receiving antenna, i.e., on the side of the antenna opposite from the transmitting source, is closer to the antenna than reflections received at right angles to the propagation direction of signals from the transmitting antenna. Because signal energy coupled to an antenna is inversely proportional to the square of the distance between the antenna and an apparent energy source, reflections from points behind the receiving antenna often have a greater influence in creating ghost images than signals reflected from structures at right angles to the receiving antenna.

A very frequently utilized antenna of the prior art for reception of strong television signals is the well-known rabbit-ear configuration. A rabbit-ear antenna is actually an adjustable dipole having a radiation pattern with a pair of nulls, presuming the rabbit-ear elements are properly adjusted. The nulls in the pattern of a rabbit-ear antenna, however, are frequently eliminated by improper adjustment of the elements, whereby ghost images from multi-path reception cannot be obviated.

A further, and perhaps more significant, problem even with properly adjusted rabbit-ear, dipole antennas is that the two nulls of the dipole pattern are located at right angles to the direction of maximum antenna sensitivity. The pattern includes a back lobe, i.e., a lobe pointing away from the transmitting source, that is generally virtually equal in amplitude to the forward or main pattern lobe amplitude. Therefore, multi-path radiation reaching the antenna in response to reflections from structures located behind the antenna are generally coupled to a receiver via a pattern lobe having the same gain as the lobe receiving direct, unreflected radiation. The rabbit-ear configuration, as a result, has a tendency to couple multi-path radiation derived from points behind the antenna to the receiver with a relatively large amplitude and augment the ghost image.

A further disadvantage with the typical rabbit-ear configuration is the degrading aesthetic qualities thereof. The unsightly appearance of a pair of elongated metal rods, forming the rabbit-ear dipole elements, mounted on a plastic base has often been criticized. While many attempts to design rabbit-ear antennas having more pleasing appearances have been made, none of these antennas, to our belief, can be considered attractive.

While satisfactory television antennas have been designed and are utilized in attic and rooftop locations, these antennas usually require a multiplicity of relatively large elements, spaced from each other by significant distances. In consequence, multi-element antennas cannot be utilized in the living quarters of a residence, such as an apartment building or a room in a single family dwelling inaccessible to a lead-in from an attic or rooftop.

The advent of truly portable receivers weighing less than 20 pounds and color receivers which are readily moved from place to place present additional problems of ghost image rejection and space with regard to television receiving antennas. With color receivers the effects of ghost images on the viewer are even greater than with black and white receivers. Objects causing ghost image reflections are found at many different locations in and about the typical residence so that with presently available portable type receivers it is usually necessary to substantially modify existing antennas each time the receiver is moved. Of course, the use of relatively large antennas is out of the question with truly portable television receivers.

According to the present invention, the problems of prior art antennas designed for strong signal areas are substantially obviated by providing a television receiving transducer or antenna having, in the horizontal plane, a substantially omnidirectional pattern and a second pattern with a plurality of nulls, e.g. a dipole-like pattern. The antenna is excited so that fields produced by the two patterns do not interact in the antenna, whereby the elements of the antenna that produce the two fields are electrically orthogonal and mutually decoupled. Because the antenna elements are decoupled from each other, the responses thereof are independent and have no effect on each other.

The responses of the antenna elements producing the two patterns are combined in a directional coupler to provide a resultant pattern for the array having substantially no side lobes, an appreciable front-to-rear lobe ratio, and a relatively broad rear null. An antenna array having such a pattern meets the requirements for substantial elimination of ghost images in a television receiver, as indicated supra. By designing the amplitude of the omnidirectional pattern to equal approximately 0.8 times the maximum amplitude of a loop type pattern having a pair of nulls and oppositely directed and phased main lobes, a resultant pattern with a substantial null (−20 db relative to the maximum amplitude of a resultant main lobe) over an angle of 100° is attained.

To achieve broad band operation over the entire VHF television band, extending between 54 and 216 megahertz (mHz.), the antenna is designed to have a resonant frequency above the highest VHF television carrier frequency. Thereby, the array has a monotonic amplitude versus frequency response over the entire VHF band, and the design of a combiner is simplified.

According to one preferred embodiment of the invention, the omnidirectional pattern is attained with a horizontal loop, while the pattern element having a plurality of nulls is derived from a dipole having its center aligned with the loop center. These antenna elements have been found to be admirably suited to provide the desired characteristics. By selecting a resonant frequency of 250 mHz. for the dipole and loop, an attractive and aesthetically pleasing array of relatively small size is obtained.

To achieve uniform frequency response of the loop and dipole over the entire VHF television band is a problem since the loop has a power versus frequency response directly proportional to a fourth power of frequency (f^4) when operated below resonance, while the dipole power versus frequency response is proportional to frequency squared (f^2). Therefore, energy coupled from the loop and dipole to the receiver must be with different frequency responses. Energy is fed from the loop and dipole to the receiver via a pair of coupled transmission lines comprising a four port directional coupler. Connected to opposite terminals of one of the lines comprising the directional coupler are the television receiver and the loop antenna element, while the dipole and a matching resistor are connected to opposite sides of the other line. The directional coupler is designed so that energy coupled from the dipole is fed to the terminals of the television receiver as a monotonic function of frequency squared. The direct connection between the terminals of the television receiver and the omnidirectional antenna element results in direct coupling of the receiver and the loop with no substantial change in the frequency response between them. Hence, the coupler modifies the frequency response from the receiver to the loop and dipole so that energy is coupled to the terminals of the television receiver from both antenna elements as a monotonic function of frequency to the fourth power over the entire VHF television band.

The loop-dipole antenna also provides reception in the UHF band, without ghost elimination properties because the directional coupler achieves 0 db coupling at a frequency of approximately 450 mHz., i.e. substantially all of the dipole energy at 450 mHz. is coupled to the television receiver. Since virtually all UHF television transmissions are in the lower portion of the UHF spectrum, i.e. between 470 and 647 mHz., and are unlikely to reach into the higher portions of the spectrum, the present antenna functions as an efficient one-wavelength dipole radiator for UHF television reception.

According to a further embodiment of the present invention, the omnidirectional pattern and the pattern having a plurality of nulls is obtained by utilizing a turnstile antenna array. The turnstile array includes four relatively orthogonal output terminals, each of which is excited with energy including real and quadrature components. The real component exciting each of the turnstile terminals is in phase to achieve omnidirectional characteristics, while the quadrature energy applied to opposite terminals is of opposite polarity for dipole mode excitation of the turnstile array. The diameter of the turnstile array is relatively small compared to a resonant frequency slightly in excess of the resonant frequency of the highest television VHF channel. By dimensioning the turnstile elements to be relatively small compared to the designed resonant frequency, i.e., the diameter of the turnstile array is between a quarter and a half wave length of the designed resonant frequency, the currents in a loop about the extremities of the turnstile elements are all in phase to achieve a loop type, omnidirectional response.

Since the dipole and loop modes are excited in phase quadrature, the vertical patterns thereof do not interact but the horizontal patterns combine to provide substantially the same pattern as is achieved with the loop and dipole elements, as discussed supra.

By selecting the resonant frequency of the turnstile antenna to be in excess of the highest frequency in the VHF band, both excitation modes of the turnstile are substantially monotonic as the fourth power of frequency over the entire band of interest. Thereby, conventional coupling elements, such as hybrids and quadrature couplers, can be utilized between the turnstile elements and the terminals of the television receiver. There is no necessity to utilize coupling networks having differing frequency versus amplitude responses for the two excitation modes of the turnstile elements.

A distinct advantage of the turnstile antenna is that both elements comprising the antenna, as well as the coupling network thereof, can be mounted within the confines of a television receiver having a dielectric casing. The selection of the antenna null can be accomplished electrically, utilizing a relatively simple and inexpensive switch between the turnstile elements and the coupling network.

It is, accordingly, an object of the present invention to provide a new and improved wave energy transducer having a radiation pattern with substantially no side lobes and a relatively wide null to the rear of the main lobe.

Another object of the present invention is to provide a new and improved wide band antenna wherein reception of multipath radiation is minimized.

It is a further object of the present invention to provide a new and improved antenna particularly adapted for television reception purposes wherein ghost images are substantially eliminated from a picture on the receiving screen.

An additional object of the present invention is to provide a new and improved television receiving antenna of relatively small size, enabling it to be carried on the receiver or in proximity to it and having ghost image elimination properties superior to prior art antennas adapted to be mounted on a receiver.

A further object of the present invention is to provide a new and improved, relatively small and inexpensive television receiving antenna that is attractive in an aesthetic sense.

A further object of the present invention is to provide a new and improved antenna adapted to be incorporated integrally within a television receiver, and having substantial ghost image elimination properties.

Yet another object of the present invention is to provide a new and improved wide band antenna adapted to be excited simultaneously with currents to produce an omnidirectional pattern and a pattern having a plurality of nulls, to provide a resultant pattern having substantially no side lobes and a relatively wide null to the rear of the main lobe.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of several specific embodiments thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a schematic diagram of a top view of an antenna and the coupling network therefor, in accordance with a preferred embodiment of the present invention;

FIG. 2 is a polar plot of the responses of the several elements comprising the antenna of FIG. 1, as well as a pattern of the entire array comprising the two elements;

FIG. 3 is a top view of a turnstile antenna comprising a second embodiment of the present invention;

FIG. 4 is a circuit diagram of the excitation network utilized for driving the antenna elements of FIG. 3 to provide the patterns of FIG. 2; and

FIG. 5 is a perspective view, with a portion in phantom, illustrating the antenna of FIGS. 3 and 4 as a unitary portion of a television receiver.

Reference is now made to FIG. 1 of the drawings, illustrating a top view of half wave dipole **11** and horizontal circular loop **12**. Half wave dipole antenna **11** includes a pair of quarter wave length radiators **13** and **14** extending in opposite directions from a common midpoint, coincident with the center of loop **12**.

Each of elements **13** and **14** of half wave dipole **11** is designed to be resonant at a frequency greater than the upper frequency boundary of the VHF television band, 216 mHz. A typical resonant frequency selected for half wave dipole **11** is 250 mHz. The diameter of loop antenna **12** is selected so that all of the current in the loop is in phase, as is achieved with loops having relatively small diameters, i.e., diameters between one-quarter and one-half of a wave length of the loop resonant frequency of 250 mHz. By selecting the length of dipole **11** and loop **12** in accordance with the criteria stated, the efficiencies of these elements in transferring power into a pair of terminals in response to horizontally polarized electromagnetic radiation, such as subsists in television transmissions, are respectively monotonic functions of frequency squared and frequency to the fourth power over the entire VHF television spectrum.

The responses of dipole **11** and loop **12** are combined and fed to terminals **17** of television receiver **18** so that the efficiency of both elements is substantially the same. Otherwise, nulling effects introduced by dipole **11** on the omnidirectional pattern of loop **12** would be variable over differing portions of the VHF television spectrum. If the response of the loop and dipole elements differs as a function of frequency over the VHF band, the same null pattern would not exist for each received television channel and ghost images would be variable as a function of a station being tuned.

To compensate for the differing frequency versus power efficiency characteristics of dipole **11** and loop **12**, coupler **19** is provided. Coupler **19** is a symmetrical directional coupler, the theory of which is fully described in the Proceedings of the Institute of Electrical Engineers, May 1955, pp. 383–392.

Directional coupler **19** includes a pair of coupled conductors **21** and **22** surrounded by shielded cable **23**. Conductor **21** is directly connected to quarter wave length element **14** of dipole **11** by balanced line **24**, while conductor **22** is connected to one of the terminals of loop **12** by balanced line **25**. The remaining terminals of loop **12** and the terminal at the end of quarter wave length element **13** are connected via lines **24** and **25** to shielded cable **23** of coupling network **19**. To the other ends of leads **21** and **22** of coupling network **19** are connected matching resistor **26** and lead-in wire **27**, the ends of which are connected to the antenna input terminals **17** of television receiver **18**.

Coupler **19** is designed so that reactive coupling between leads **21** and **22** results in a monotonic attenuation of energy between leads **24** and **27** that is directly proportional to frequency squared over the VHF television band. Since energy coupled between lines **24** and **27** is a function of frequency squared over the entire VHF television spectrum, the efficiency in transferring power from the dipole **11** to the terminals **17** of television receiver **18** is a function of frequency to the fourth power. Since a direct connection exists between the terminals of loop **12** and antenna terminals **17** of receiver **18** via lines **22**, **25** and **27**, and the frequency response of loop **12** is a monotonic function of frequency to the fourth power over the entire VHF band, the frequency responses of both the dipole and loop elements, in combination with coupler **19**, are proportional to monotonic functions of frequency to the fourth power over the entire VHF television band.

To eliminate the effects of horizontally polarized radiation components, as may be derived from multi-path radiation, on the signal coupled to terminal **17** of receiver **18** and decouple the effects of currents in the loop and dipole from each other, the responses of loop **12** and dipole **11** in the vertical plane are isolated. The responses of dipole **11** and loop **12** in the vertical plane are isolated by exciting the loop and dipole with signals displaced in phase from each other by 90°, as is attained by suitable selection of the length of lines **24** and **25**, or the insertion of a lumped parameter phase shifter in one of the lines. The relative phase shift introduced by lines **24** and **25** between coupler **19** and dipole **11**, as well as loop **12**, is governed by the phase shift of coupler **19** between the excitation end thereof connected to line **27** and the ends connected to lines **24** and **25**.

For design purposes in eliminating multi-path radiation causing ghost images on the picture of receiver **18**, it is necessary for the maximum response of dipole **11** to exceed that of loop **12** by a predetermined amount, as indicated by the radiation pattern plots of FIG. 2. To achieve the desired maximum amplitude of the patterns, a resistor is inserted in one of the lines **24** or **25**. In the present specifically considered embodiment, it is assumed that the radiation efficiency of dipole **11** is in excess of the radiation efficiency of loop **12**, whereby resistor **28** is connected in shunt with the leads comprising balanced line **24**.

Giving further consideration to the antenna radiation pattern of FIG. 2, in the horizontal plane the pattern of loop **12** comprises circle **31** having radius B, while the horizontal pattern of dipole **11** comprises two circles of equal diameter A and a common point of tangency at the center of circle **31**. Patterns **31** and **32** of loop **12** and dipole **11** are combined to provide the resultant pattern indicated by the cardioid-like pattern **33**. Main lobe **34** of pattern **33** has an amplitude equal to the sum of the diameter of one of the circles of pattern **32** and the radius of pattern **31** since the loop and dipole currents are in phase along the line $\theta=0$. In contrast, the rear, or secondary, lobe **35** of pattern **33** has an amplitude equal to the difference between the diameter of one of the circles **32** and the radius of circle **31** because the loop and dipole currents are 180° displaced along the line $\theta=\pi$. There is a very low amplitude response in the side lobes of pattern **33**, whereby multi-path radiation reaching the antenna is severely attenuated compared to radiation reaching the antenna directly from a radiating source, presuming that the maximum amplitude of lobe **34** is directed at a site of television transmission.

To attain a front-to-back ratio of 20 db, i.e., a ratio of the maximum amplitude of the power in lobe **34** to the maximum amplitude of the power in lobe **35**, equal to 13.3, it can be shown that $B=0.819A$. The same selection of the relative values of B and A results in a relatively broad null encompassing approximately 100° for the 20 db rejection region, in resultant pattern **33**. In other words, at least a 20 db ratio between the maximum amplitude of lobe **34** to the maximum amplitude of lobe **35** subsists for an angle of approximately 50° to either side of $\theta=\pi$ in the polar diagram of FIG. 2.

The relatively board null of pattern **33** to the rear of the maximum response of lobe substantially prevents multi-path radiation from effecting the image on the screen of television receiver **18**, thereby eliminating ghosts from the image on the television receiver screen. As discussed supra, the broad null attained by the present invention is derived by properly selecting the value of resistor **28** in line **24**.

In normal operation, dipole **11** and loop **12** are mounted on a common base, not shown, placed on the upper surface of television receiver **18**. Main lobe **34** of the resultant pattern is directed toward a television transmission site originating the signal desired to be detected by placing arms **13** and **14** at right angles to the direction of direct radiation propagation from the site. Thereby, multi-path radiation reaching the array from the rear of the antenna of from the sides thereof is considerably reduced in amplitude relative to the amplitude of directly received radiation to cause substantial elimination of ghost images from the picture of television receiver **18**. When it is desired to change the channel being viewed on receiver **18**, the base carrying dipole **11** and loop **12** can be rotated, or dipole **11** only can be rotated so that arms **13** and **14** are approximately at right angles to direct propagation from the new transmission site.

The antenna of the present invention acn be made aesthetically pleasing because of its unobtrusive appearance. In particularly, the total length of dipole element **11** is only slightly in excess of two feet, while the diameter of loop **12** is approximately eighteen inches, if the resonant frequencies thereof are designed as 250 mHz. Since dipole **11** and loop **12** can be placed in horizontal planes only slightly removed from each other because their vertical patterns are decoupled, it is apparent that very little space is required for the antenna of the present invention in comparison with the commonly employed rabbit-ear configuration. By proper aesthetic design, the antenna of the present invention can actually be made to have a pleasing, modernistic appearance.

While the antenna of FIG. 1 can be designed to have a pleasing appearance, it may be unattractive to some individuals and should be located in a fairly readily accessible location so that dipole **11** can be rotated mechanically by hand or a motor, if cost is not an important factor.

To avoid the requirements for an antenna that must be located exteriorly of a television receiver and mechanically rotated, the present invention envisages the embodiment of FIGS. 3–5. The antenna configuration of FIGS. 3–5 is a turnstile antenna including four ports or terminals **41–44** located at 90° with respect to each other from center **45** of the antenna. Respectively connected to each of terminals **41–44** is a separate, radially extending lead **46–49**. At the ends of leads **46–49** remote from terminals **41–44** are arcuate leads **51–54**, each of which subtends approximately a 45° arc about center **45** and extends in a clockwise direction from the radially extending lead to which it is connected. Connected to each of leads **51–54** is a pair of parallel arcuate leads **55–62**. Leads **55–58** each subtend an arc of 90° about center **45**, while each of inner leads **59–62** extends arcuately for 45° about center **45** and extends radially inwardly toward one of the terminals **41–44**. Connected to the junction of each of the arcuate leads **51–54** and the pair of parallel leads extending therefrom is a ground plane, as indicated by the grounded leads **63**. To complete the structure of the turnstile antenna array, leads **64–67** are provided. Leads **64–67** extend radially from an area close to terminals **41–44** to regions proximate arcuate leads **51–54** and are bent in a counterclockwise direction to define arcuate paths, each subtending an angle of approximately 45°.

Thus, the radially extending and arcuate leads connected to each of the terminals **41–44** of the turnstile antenna are positioned in relatively close proximity with a pair of other leads, to provide reactive coupling and establish a turnstile array capable of being excited with loop-like and dipole-like patterns **31** and **32**, as well as a resultant pattern **33** as indicated by FIG. 2. As in the embodiment of FIG. 1, the resonant frequency of the array of FIG. 3 is selected to be slightly in excess of the highest frequency in the VHF television band, with a value of approximately 250 mHz. being selected. Thereby, the amplitude versus frequency response of the turnstile is a monotonic function over the entire VHF band being received for both the loop and dipole excitation modes.

Loop mode excitation of the turnstile configuration of FIG. 3 is derived by supplying currents of identical phase

to each of terminals **41–44**. The in-phase currents supplied to terminals **41–44** establish a loop-like response since the array has a relatively small diameter, between one-quarter and one-half a wave length of the designed loop resonant frequency, whereby the in-phase currents supplied to the loop are maintained in phase in the far field. In contrast, dipole mode excitation of the turnstile array of FIG. 3 is obtained by supplying oppositely phased currents to oppositely oriented terminals of the array. For example, energy of phase $\Phi=0$ is supplied to terminals **41** and **42** while energy of phase $\Phi=\pi$ is supplied to terminals **43** and **44**. In the alternative, terminals **42** and **44** can remain unexcited while energy of phases $\Phi=0$ and $\Phi=\pi$ are supplied to terminals **41** and **43**, respectively. Dipole excitation for the turnstile array occurs in response to terminals **41**, **42** being excited with phase $\Phi=0$ and terminals **43**, **44** being excited with phase $\Phi=\pi$ because such excitation results in current flowing counterclockwise in arcuate conductors **51**, **52** and clockwise in arcuate conductors **53**, **54**. In the far field, these currents produce a radiation pattern equivalent to a dipole having an axis aligned with lines **46** and **48**, whereby a radiation pattern including two circles having their diameters aligned with leads **47** and **49** and a pair of nulls extending along leads **46** and **48** is established. To provide isolation for loop and dipole excitation modes of the turnstile of FIG. 3, a relative phase difference of $\pi/2$ must exist for the loop and dipole currents.

An important distinction between the loop and dipole antenna of FIG. 1 and the turnstile configuration of FIGS. 3–5 is that the turnstile loop and dipole mode excitations have similar frequency versus amplitude responses that are monotonic functions of frequency to the fourth power below the resonant frequency of the turnstile array. Thereby, the loop and dipole mode excitation applied to terminals **41–44** is through a network having similar, broad band frequency versus amplitude responses for both excitation modes. Of course, the important similarity between the antenna arrays of FIGS. 1 and 3 is that the loop and dipole mode excitations thereof result in substantially identical patterns **33**, having a relatively wide null to the rear of the main lobe **34** and virtually no side lobes.

To excite the turnstile antenna of FIG. 3 in the manner indicated, the coupling network of FIG. 4 includes, broadly, a switch **71** excited by hybrid **72**, which in turn is fed from quadrature coupler **73** that is connected to the antenna terminals **17** of television receiver **18**. To achieve similar frequency versus amplitude responses between terminals **17** and the turnstile array for both the dipole and loop excitation modes throughout the VHF television band, hybrid **72** and quadrature coupler **73** are of the wide band type, having constant frequency response throughout the VHF television spectrum.

Switch **71** includes four arcuate stator contacts **74–77**, respectively connected to terminals **41–44** of the turnstile array. Selectively bridging only a pair of arcuate contacts **74–77** are ganged arcuate rotor contacts **78** and **79**. Rotor contacts **78** and **79** are rotatable to four separate, predetermined arcuate positions, whereby: terminals **41** and **42** are connected together through rotor contact **78** while terminals **43** and **44** are connected together through rotor contact **79**; terminals **42** and **43** are connected together through rotor contact **78** while terminals **41** and **44** are connected together through rotor contact **79**; terminals **43** and **44** are connected together through rotor contact **78** while terminals **41** and **42** are connected together through rotor contact **79**; and terminals **41** and **44** are connected together through rotor contact **78** while terminals **42** and **43** are connected together through rotor contact **79**.

Rotor contacts **78** and **79** are connected through suitable brushes, not shown, via lines **81** and **82** to arms **83** and **84** of hybrid **72**. Hybrid **72** is excited with energy in relative quadrature phase relationship at arms **85** and

86 with energy represented as a and $j\sqrt{1-a^2}$, respectively, where: a is an attenuation factor introduced by quadrature coupler 73, and $j=\sqrt{-1}$.

Energy fed to arm 86 is attenuated by resistor 87, whereby the resultant turnstile pattern has a shape indicated by cardioid-like pattern 33, FIG. 2. Because of resistor 87, radiation derived from arms 83 and 84 of hybrid 72 is respectively represented as:

$$a+jb\sqrt{1-a^2} \text{ and } a-jb\sqrt{1-a^2}$$

The values of a and b, as well as the radiation efficiency of the turnstile array for the loop and dipole modes, enable the values of A and B for patterns 31 and 32 to be derived for the embodiment of FIGS. 3–5 with the same criteria as for the embodiment of FIG. 1.

Excitation for arms 85 and 86 of hybrid 72 is from quadrature output ports 88 and 89 of wide band quadrature coupler 73. Input port 91 of coupler 73 is connected to one of the antenna terminals 17 of television receiver 18, the other terminal of which is grounded, hence connected to a ground plane conductor (not shown) for each of the leads and coupling elements of the FIG. 4 network. Connected to the remaining terminal 92 of quadrature coupler 73 is matching resistor 94.

In normal usage in conjunction with a television receiver, the turnstile antenna of FIG. 3 is mounted in a horizontal plane slightly beneath the upper surface of a television receiver having a plastic casing 95, as illustrated in FIG. 5. Casing 95 includes a hinged door 96 on its upper surface 97, whereby access may be had to knob 98 for rotating ganged rotor contacts 78 and 79. Rotation of knob 98 establishes the four different connections of terminals 41–44 to the coupler network of FIG. 4. As knob 98 is rotated to one of the four positions thereof, the main lobe 34 of pattern 33 is rotated 90°.

With rotors 78 and 79 in the position illustrated by FIG. 4 and assuming the loop and dipole excitation currents are additive as derived from arm 83 of hybrid 72 and subtractive as derived from arm 84 of the hybrid, the resultant pattern main lobe is pointed in a direction to the right of the array and aligned with lead 47 and terminal 42, while a relatively broad null exists to the left of the array and has its center aligned with lead 49 and terminal 44. If knob 98 is rotated, whereby the contacts 78 and 79 are shifted clockwise 90°, the main lobe of the pattern is shifted clockwise 90°. By shifting the main lobe 90° in steps, the main lobe can be pointed approximately at all VHF television transmission sites in the region and substantial elimination of ghosts is attained because of the relatively broad null to the rear of the main lobe.

While we have described and illustrated several specifiic embodiments of our invention, it will be clear that variations in the details of the embodiments specifically illustrated and described may be made without departing from the true spirit and scope of the invention as defined in the appended claims. For example, other elements than loops and dipoles or turnstiles can be utilized for the antenna of the present invention as long as excitation for the omnidirectional pattern is 90° out of phase with excitation creating the dipole-like pattern. Exemplary of other elements which may be utilized are conical antennas, discones, and slots. It is also to be understood that the resultant pattern of the turnstile configuration of FIGS. 3–5 can be changed electrically by means other than the switch specifically illustrated. For example, phase shifting arrays can be employed, although they are generally thought to be excessively expensive for commercial adaptation.

We claim:

1. In combination, a wave energy transducer array having means for establishing in the same plane an omnidirectional radiation pattern and a second radiation pattern having a plurality of nulls and two oppositely directed and phased main lobes, means for simultaneously exciting both patterns of said array so that currents in said patterns in a plane at right angles to said same plane are decoupled and the maximum amplitude of the second pattern relative to the amplitude of the omnidirectional pattern produces a resultant pattern having a relatively broad substantial null to the rear and sides of a main lobe.

2. The combination of claim 1 wherein said omnidirectional and second patterns are respectively loop type and dipole type patterns.

3. The combination of claim 2 wherein the amplitude of the loop type pattern is approximately 0.8 times the maximum amplitude of the dipole type pattern.

4. The combination of claim 1 wherein said means for establishing the omnidirectional and second patterns respectively have radiation efficiencies directly proportional to first and second monotonic functions of frequency over a relatively wide frequency band, said coupling means including means for exciting said array so that substantially the same radiation efficiency exists throughout said band for excitation of both said patterns from a single excitation point.

5. The combination of claim 4 wherein said array includes a first element having loop-like pattern and frequency characteristics and a second element having dipole-like pattern and frequency characteristics for respectively establishing said omnidirectional and second patterns, said elements both having resonant frequencies above said band, said exciting means including means for coupling energy between said loop-like element and said point as a constant function of frequency within said band and for coupling energy between said dipole-like element and said point as a monotonic function of frequency squared within said band.

6. The combination of claim 5 wherein said exciting means includes a pair of lines coupled only reactively to each other, one of said lines being connected to said point and said first element, the other of said lines being connected to said second element.

7. The combination of claim 4 wherein said array includes a plurality of elements for establishing said patterns with the same amplitude versus frequency response throughout said band.

8. The combination of claim 7 wherein said array comprises a turnstile antenna having four orthogonally arranged elements, means for exciting all of said elements with energy of the same amplitude and reference phase while exciting a pair of oppositely disposed ones of said elements with energy of the same amplitude and opposite phases, each of said opposite phases being displaced from the reference phase $\pi/2$ radians.

9. The combination of claim 8 wherein said coupling means includes electric means for selectively directing the main beam of the resultant pattern in a plurality of directions.

10. The combination of claim 9 wherein said electric means includes four contacts respectively connected to said elements and a pair of contacts each always selectively connected only to a pair of said four contacts, and means for exciting both said pair of contacts with energy of the reference phase and for exciting different ones of said pair of contacts with oppositely phased energy displaced in phase $\pi/2$ radians from the reference phase.

11. An antenna particularly adapted for reception of television signals throughout the VHF television spectrum in strong signal areas and for substantially eliminating ghost images from a television receiver picture comprising an antenna array having means for establishing in the horizontal plane an omnidirectional radiation pattern and a second pattern including energy in phase and out of phase with energy in the omnidirectional pattern, said array being resonant for both said patterns at a frequency above the VHF spectrum, and coupling means for exciting said array so that substantially the same radiation efficiency exists between antenna terminals of a television receiver

and said array for both said patterns and a resultant pattern in the horizontal plane from said omnidirectional and second patterns has a relatively broad substantial null to the rear and sides of a main beam.

12. The antenna of claim **11** wherein said omnidirectional and second patterns are respectively loop type and dipole type patterns, said loop type pattern having an amplitude approximately 0.8 times the maximum amplitude of the dipole type pattern.

13. The combination of claim **11** wherein said means for establishing the omnidirectional and second patterns respectively have radiation efficiencies directly proportional to first and second monotonic functions of frequency over said spectrum, said coupling means including means for exciting said array so that substantially the same radiation efficiency exists throughout said spectrum for excitation of both said patterns from said antenna terminals.

14. The combination of claim **13** wherein said array includes a first element having loop-like pattern frequency characteristics and a second element having dipole-like pattern and frequency characteristics for respectively establishing said omnidirectional and second patterns, said exciting means including means for coupling energy between said loop-like element and said terminals as a constant function of frequency within said spectrum and for coupling energy between said dipole-like element and said terminals as a monotonic function of frequency squared within said spectrum.

15. The combination of claim **14** wherein said exciting means includes a pair of lines coupled only reactively to each other, one of said lines being connected to one of said terminals and said first element, the other of said lines being connected to said second element.

16. The combination of claim **13** wherein said array includes a plurality of elements for establishing said patterns with the same amplitude versus frequency response throughout said spectrum.

17. The combination of claim **16** wherein said array comprises a turnstile antenna having four orthogonally arranged elements, means for exciting all of said elements with energy of the same amplitude and reference phase while exciting a pair of oppositely disposed ones of said elements with energy of the same amplitude and opposite phases, each of said opposite phases being displaced from the reference phase $\pi/2$ radians.

18. The combination of claim **17** further including a dielectric television receiver case containing said turnstile antenna interiorly thereof and mounting said turnstile antenna in the horizontal plane.

19. The combination of claim **18** wherein said coupling means includes switch means for selectively directing the main beam of the resultant pattern in a plurality of directions.

20. The combination of claim **19** wherein said switch means includes four contacts respectively connected to said elements and a pair of contacts each always selectively connected only to a pair of said four contacts, and means for exciting both said pair of contacts with energy of the reference phase and for exciting different ones of said pair of contacts with oppositely phased energy displaced in phase $\pi/2$ radians from the reference phase.

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