March 10, 1970 D. H. WELLS 3,500,426

MAGNETICALLY DRIVEN ANTENNA ARRAY

Filed June 3, 1966 3 Sheets-Sheet 1

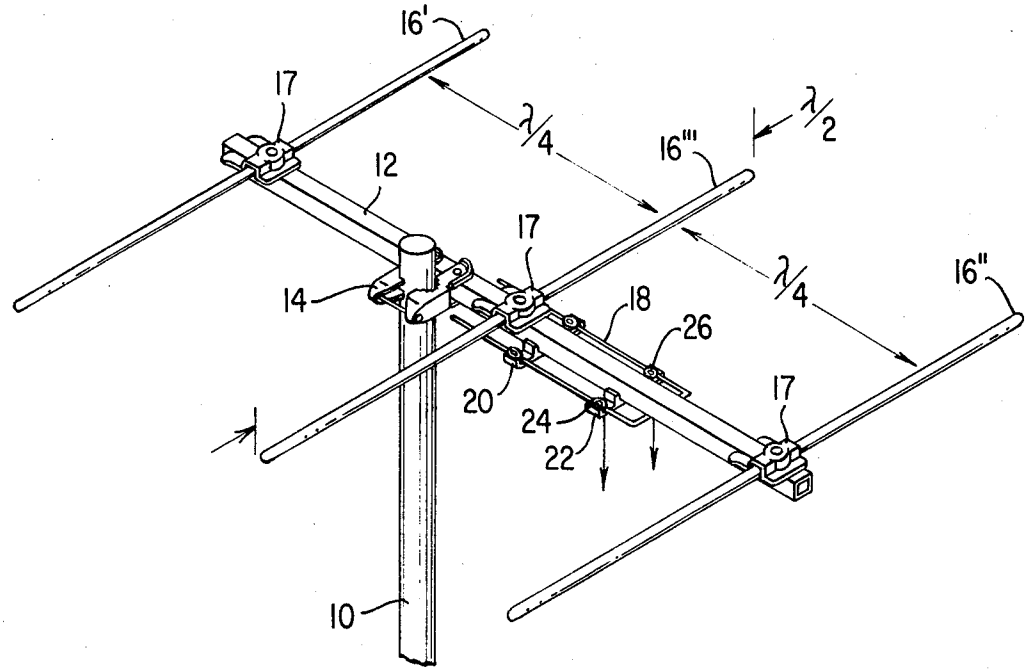


Fig. 1

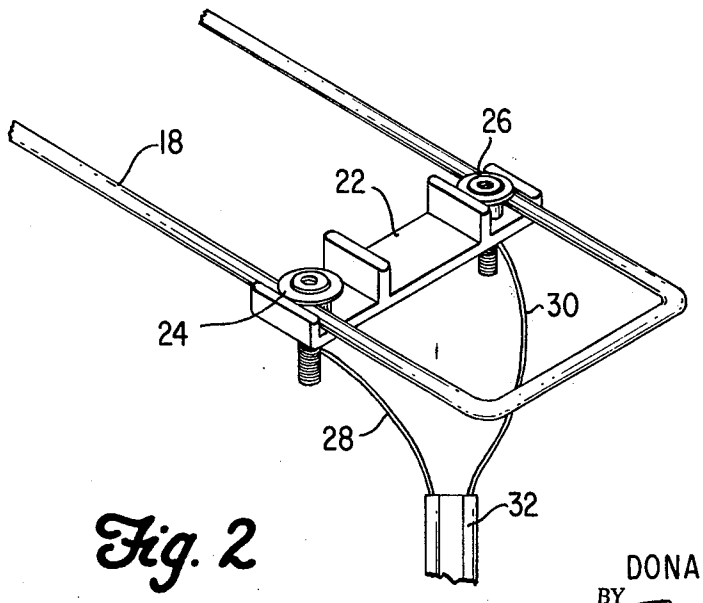


Fig. 2

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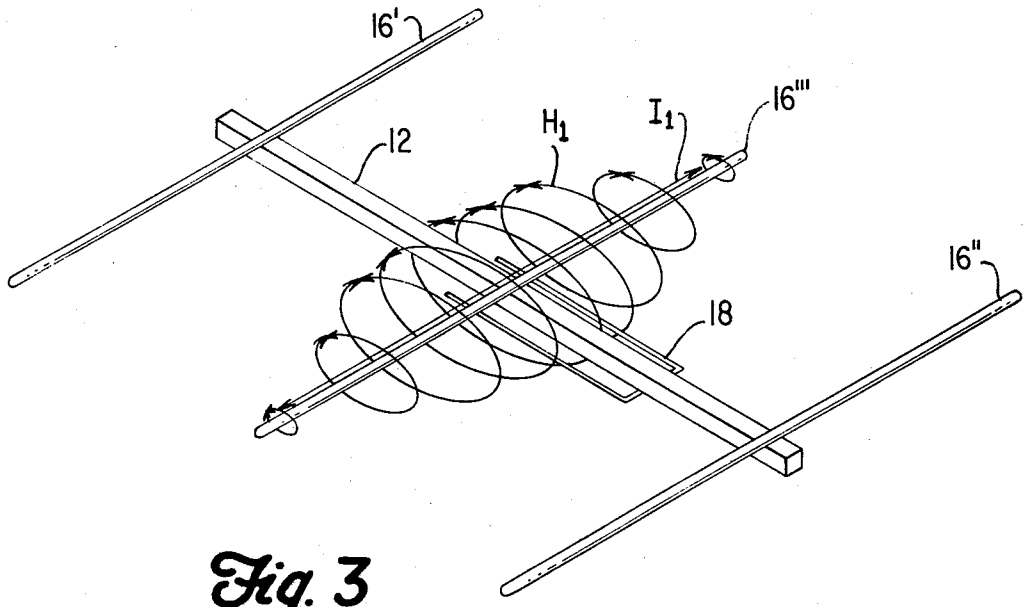


Fig. 3

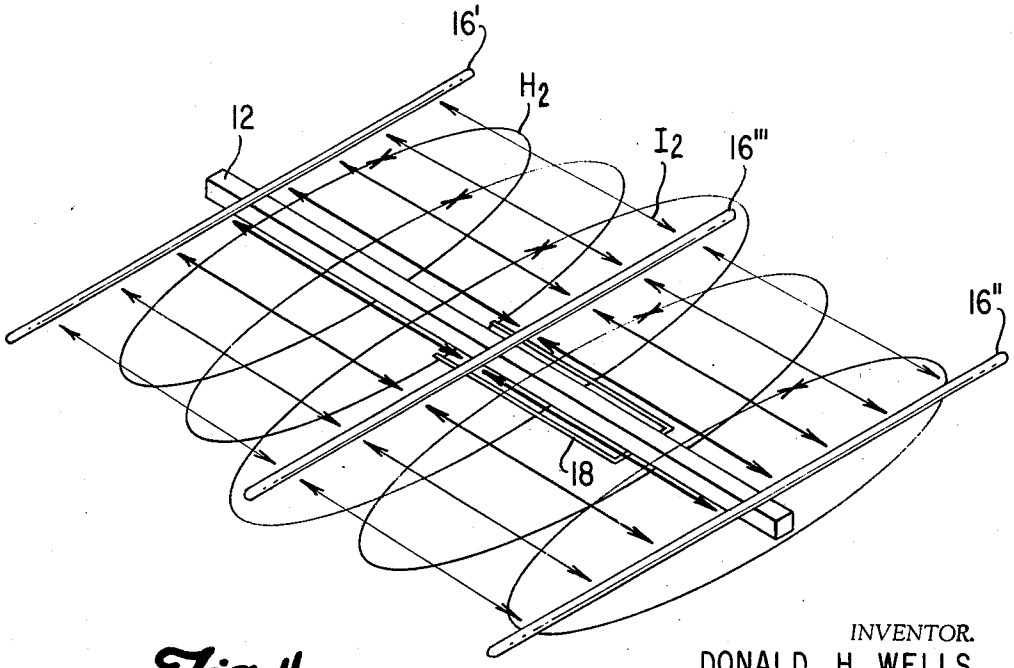


Fig. 4

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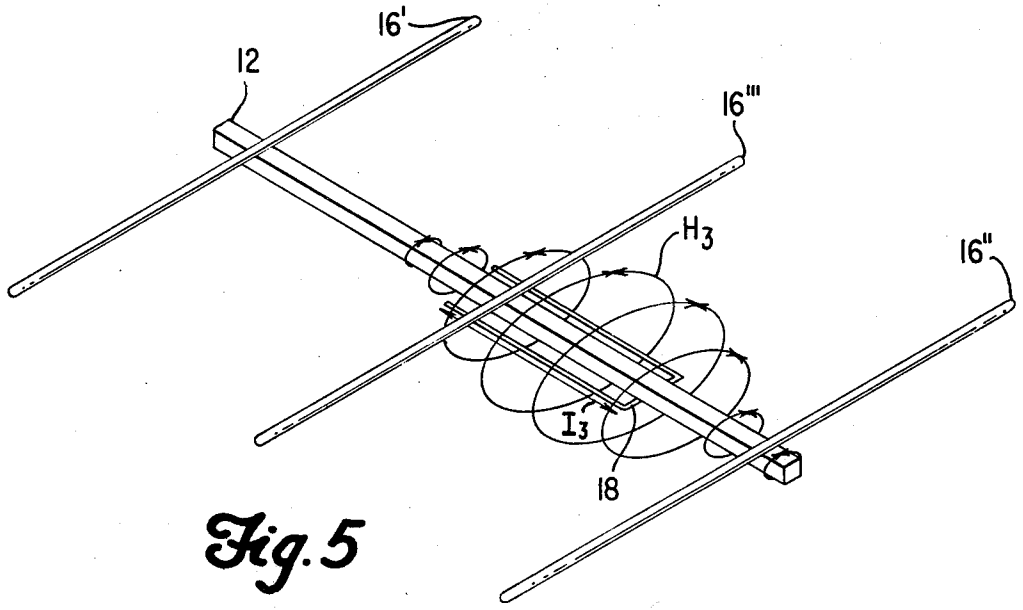


Fig. 5

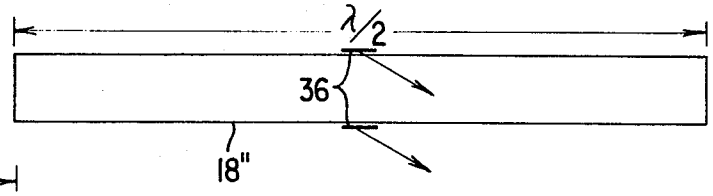


Fig. 7

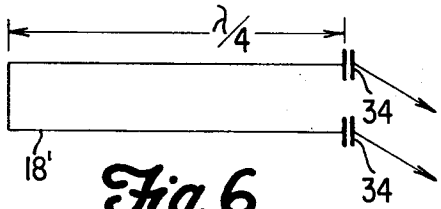


Fig. 6

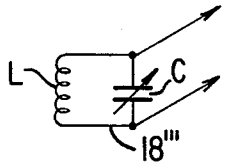


Fig. 8

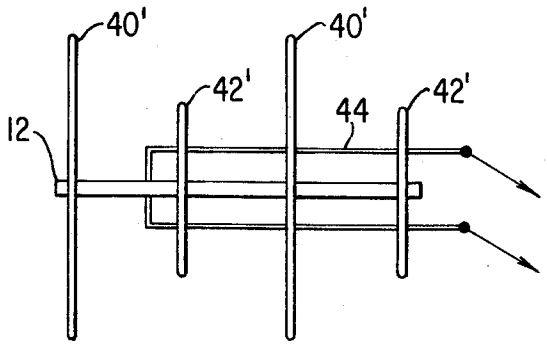


Fig. 10

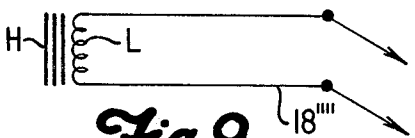


Fig. 9

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Patented Mar. 10, 1970

3,500,426

MAGNETICALLY DRIVEN ANTENNA ARRAY

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Continuation-in-part of application Ser. No. 500,931, Oct. 22, 1965. This application June 3, 1966, Ser. No. 562,041

Int. Cl. H01q *19/30*

U.S. Cl. 343—819 2 Claims

ABSTRACT OF THE DISCLOSURE

A magnetically driven antenna array in which all of the antenna dipole elements are parasitic. The array is driven by an independent means consisting of a section of transmission line. The incident plane wave of energy from the transmitter source induces currents on the parasitic dipoles of the array, establishing a secondary or reradiated field. The total electromagnetic field in the vicinity of the array is a combination of the secondary fields from all of the antenna elements and the incident field. In its simplest form, this field is a standing wave, whose vector "H" (magnetic lines of force) near the axis of the array where the driven element is placed, establishes a strong magnetic flux which links the loop formed by the section of transmission line. The time varying flux drives the transmission line by inducing voltages and currents on it that can be conveniently fed to the associated receiver.

This is a continuation-in-part of application Ser. No. 500,931, now abandoned, filed Oct. 22, 1965.

SUMMARY OF THE INVENTION

According to the invention, there is provided an antenna array comprising a support; at least two spaced apart electrically continuous antenna elements mounted on the support, the antenna elements being parallel to one another and residing in the same plane, and spaced apart at substantially one quarter of a wave length of the operating frequency of the antenna array; an inductance element mounted on the support and being insulated from the antenna elements and aligned and dimensioned for inductive coupling with the magnetic fields established between the antenna elements; lead coupling means on the inductance element; and means electrically coupled to the lead coupling means for delivering a signal to a receiver, whereby the lead coupling means are positioned on the inductance element at a point where the impedance of the inductance elements is substantially equal to the impedance of the means for deliivering the signal to the receiver.

FIGURE 1 is a perspective view of an antenna system incorporating the principles of the present invention;

FIGURE 2 is an enlarged fragmentary view of the feed point and the inductance element;

FIGURES 3, 4, and 5 diagrammatically illustrate the current and magnetic field configuration established by the electromagnetic energy being recieved by the antenna system illustrated in FIGURES 1 and 2;

FIGURES 6 through 9 diagrammatically illustrate various electrical configurations for the inductive element of FIGURES 1 and 2; and

FIGURE 10 illustrates a further embodiment capable of a broad band application.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring to the drawings and more particularly to FIGURES 1 and 2, there is illustrated an antenna system suitably mounted on a mast **10**. The antenna system includes a boom **12** which is disposed generally in a horizontal plane and is mechanically coupled to the mast **10** by a mast clamp arrangement **14**. The boom **12** is typically formed of a lightweight, conducticve, weather resistant material such as, for example, aluminum tubing. It will be understood that the boom **12** can likewise be fabricated from electrically insulating material such as, for example, a fiber glass reinforced plastic.

Spaced along the length of the boom **12**, there is disposed a plurality of antenna dipole elements **16**. The dipole elements **16** are preferably formed of unitary lengths of a light weight, weather resistant, electrically conductive material such as, for example, aluminum tubing. The spacing between and the length of each of the dipole elements **16** are so arranged as to obtain the desired directivity and response pattern of the antenna system under consideration. In a unidirectional antenna system, the dipole elements **16** would normally be spaced at $\lambda/4$ of the operating frequency of the antenna, and the dipole element **16'** toward the direction of the received signal would be resonant at a frequency slightly higher than the operating frequency and the dipole elements **16''** at the end opposite the direction of the received signal would be resonant at a frequency slightly lower than the operating frequency of the antenna system. The dipole element **16'''** would be resonant at the operating frequency.

Disposed in relatively close relation to and in a plane parallel to the antenna dipole elements **16'**, **16''**, and **16'''**, there is disposed a resonant inductance element **18**. The resonant inductance element **18** is typically mechanically secured to the bottom **12** by a pair of insulating brackets **20** and **22**. The element **18** in the embodiment illustrated in FIGURES 1 and 2 is generally U-shaped and is approximately $\lambda/4$ in length from the closed end or base to the open ends. The element **18** is resonant at the operating frequency of the antenna system, and the limbs of the element are parallel to one another and arranged symmetrically above the centers of the antenna elements and extend perpendicularly to the antenna elements and in a plane parallel to, and closely spaced from, the array.

The bracket **22** is provided with electrical terminals **24** and **26** which are adapted to be coupled to respective transmission line leads **28** and **30** of a transmission line **32** commonly referred to in the trade as "twin-lead." The terminals **24** and **26** are in electrical contact with the resonant inductance element **18**, and are positioned along the length thereof at a point where the impedance of the resonant inductance element **18** is equal to the impedance of the transmission line **32**.

It will be understood that various numbers of dipole elements **16** may be employed and the number employed is tpically a function of the gain of the antenna system. Accordingly, as the number of such dipole elements is increased, the overall gain of the antenna is increased.

Now referring to FIGURE 1, the transmitted electromagnetic energy to be received by the antenna system is propagated in a direction from element **16'** towards element **16''**. The electromagnetic energy is normally polarized in a horizontal plane which is the same plane as the plane of the dipole elements **16'**, **16''**, and **16'''**. As the energy arrives at dipole element **16'**, a portion of it is absorbed. It will be understood that the element **16'** is resonant at the frequency of the incoming signal. Since there is no resistance load terminating dipole element **16'**, i.e. the element is electrically continuous all of the absorbed energy will be returned to space in an in-phase relationship with the energy which is arriving at dipole element **16'''**. Since there is no resistance load terminating dipole element **16'''**, all of the absorbed energy will be returned to space in an in-phase relationship with the incoming wave front and with the energy arriving at dipole element **16''**. The dipole element **16''** is resonant at a fre-

quency slightly lower than the frequency of the incoming signal and therefore tends to reflect the energy back to the dipole element **16'''**. At each of the dipole elements upon the reception of the incoming or received electromagnetic energy, there is caused a flow of current I, along the dipole elements **16'**, **16''**, **16'''** and an associated magnetic field H, as diagrammatically illustrated in FIGURE 3. Since all of the energy which arrives at the dipole elements is returned to space, a flow of current I_2 is caused to pass between the dipole elements of the antenna, as diagrammatically illustrated in FIGURE 4. It will be observed that associated with the current I_2 there is established a magnetic field H_2. The magnetic field H_2 is oriented in a plane generally perpendicular to the plane of the magnetic field H_2 and is parallel or coplanar with the dipole elements **16'**, **16''**, **16'''** and simultaneously perpendicular to the plane of the resonant inductance element **18**.

The magnetic field H_2 effectively cooperates with the resonant inductance element **18** to induce therein a flow of current I_3 as shown in FIGURE 5. The induced current I_3 establishes an associated magnetic field H_3 as diagrammatically illustrated in FIGURE 5. The magnetic field H_3 is coplanar with and coupled to the magnetic field H_2 associated with the current flow I_2 which may be referred to as the free space current flow.

As will be apparent from the diagrammatic illustrations of FIGURES 3 and 4 the induced magnetic field H_1 and the induced magnetic field H_2 are oriented perpendicularly with respect to each other and, due to this fact, there will be no coupling effect of the magnetic field H_3 around the resonant inductance element **18** (FIGURE 5). Therefore, the coupling of element **18** is with respect to the magnetic fields H_2 and H_3 and in conductive electrical isolation from the dipole elements **16'**, **16''**, and **16'''**. Accordingly, the electrical characeteristics of the element **18** are likewise in electrical isolation from the dipole elements **16'**, **16''**, and **16'''** since there is no mutual conductive, inductive or capacitive coupling. Therefore, in designing an antenna system for receiving a given portion of the energy spectrum, the element **18** becomes an independent design parameter, i.e., it is dependent only on the wave length for which the array is designed.

In operation, the magnetic fields H_2 and H_3 induce the current I_3 in the element **18**. This current I_3 is delivered to the transmission line **32** through the terminals **24** and **26** and the associated leads **28** and **30**, respectively. The transmission line **32** may be coupled to a suitable receiving device such as a television receiver, FM receiver, radio receiver, etc. Manifestly, although the above description has specifically been concerned with the antenna as an integral part of a receiving system, it could likewise be satisfactorily employed as an integral part of a transmitting system.

The inductive element may be of configuration other than specifically illustrated and described with reference to FIGURES 1 through 5. Other configurations would include the embodiments illustrated in FIGURES 6 through 9. The element **18'** illustrated in FIGURE 6 includes capacitive means **34** for capacitively coupling the element to the transmission line. The loop has parallel longitudinal limbs arranged symmetrically about the centers of the antenna elements and extend perpendicularly to the antenna elements in a plane parallel to and closely spaced from the array of antenna elements.

FIGURE 7 is an extension of the element **18'** of FIGURE 6. There is shown an element **18''** which is a complete loop having capacitive means **36** for capacitively coupling the element to a transmission line.

FIGURE 8 shows another embodiment of the inductively coupled element wherein the element **18'''** is in the form of an inductance-capacitance (L-C) circuit. Such an arrangement effectively reduces the overall physical length of the element from those shown in the other embodiments, but functions similarly.

FIGURE 9 shows another embodiment of the inductively coupled element wherein the element **18''''** has a coil L and an associated magnetic core.

There is illustrated in FIGURE 10 an antenna system employing the principles of the invention wherein the arrangement is capable of multiband application. More particularly, the arrangement is suitable for dual frequency application. A boom **12** is disposed to support a pair of spaced apart dipole elements, **40'** resonant at a given frequency, and another pair of spaced apart dipole elements, **42'** interdigitated between the elements, **40'** and resonant at another frequency. An inductance drive element **44**, similar to the earlier described elements **18**, is suitably mounted to be inductively coupled to the magnetic field established by the dipole elements. The drive element **44** is typically equal in effective length to one half the wave length of the lower frequency, while it would be equal in length to the wave length of the higher frequency of energy to be received. The arrangement has been found to function generally as described above with respect to FIGURES 1 to 5.

While it is not certain that the theory of the antennae illustrated and described above functions exactly as explained, tests have borne out that the system embodies excellent operating characteristics and is simpler in construction than heretofore known antenna systems. However, in order to more fully understand the operation of the antenna systems described above, a review of the nature of electromagnetic radiation will be of assistance.

A transverse electromagnetic traveling wave is a wave in which both the electric and magnetic fields are transverse to the direction of travel and to each other. The velocity of propagation or speed of travel of such a wave is equal to the speed of light, and the frequency or wave length is the distance between successive points of the same electrical phase in the wave. As a general rule, it may be stated that power may not be taken from a traveling wave unless it is first acted upon in such a manner as to create a standing wave.

Standing waves are established as a result of two waves of the same frequency traveling in opposite directions. Standing waves in space result when an electromagnetic signal is reflected back toward the signal source. Standing waves on a transmission line exist only when a signal is reflected back from a load. In order for an antenna element to radiate or receive power, it is necessary for a standing wave to exist on the antenna element. Power may be taken from the standing wave because the wave is in effect standing still in one place rather than traveling at the speed of light, as in the case of the traveling wave, and the fields associated with the wave are alternately reversing their polarity at the speed of the wave frequency.

As a general rule it is necessary to create a standing wave before power may be taken from an incoming wave front. With the above in mind, let us examine a Yagi type antenna array and observe what occurs as a traveling wave arrives along the axis of the array. For simplicity, we will now not consider the standing waves that exist on the dipole elements, but merely look at the waves that exist in space as a result of the parasitic elements. Since the parasitic elements of the Yagi array are not terminated in a load, all of the energy received by the elements will be returned to space. The incoming traveling wave may be represented by a sine wave. As the sine wave arrives at the dipole director a voltage is impressed thereon. This energy is returned to space in the form of a traveling wave which may typically be represented by another sine wave. Since the dipole element is bidirectional, half of the power will travel to the right of the element, and the other half of the power will travel to the left of the element. The two waves will travel until they meet the reflector dipole where they are reflected back toward the incoming signal. The resultant of the incoming traveling wave signal and the reflected traveling wave will be a standing wave.

It will now be appreciated that we have satisfied the first requirement for taking the power from the traveling wave without considering the function of the dipole element; namely, a standing wave has been established. Since a standing wave exists in space in the antenna arrangement as explained above, a driven dipole element is not necessary to take power from the antenna array. A section of the transmission line arranged to provide mutual flux linkage with the magnetic field of the standing wave will satisfy the requirements for the driven means and will provide advantages over a driven dipole element.

In lieu of a driven dipole, as in the case of an antenna operating in the electric field, a driven means is inductively coupled to the electromagnetic energy flowing between the associated dipole elements. Such an arrangement provides an inductive coupling between the driven means and magnetic field of the resultant standing wave. Any impedance from a very low to a very high value may be found at points along the driven means facilitating a very precise impedance match to the associated transmission line, thereby greatly simplifying the antenna design problems. With the foregoing description, it is considered that one skilled in the art may be appreciative of the functional aspects of the antenna systems illustrated and described herein.

In accordance with the provisions of the patent statutes, I have explained the principles and mode of operation of my invention, and have illustrated and described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

What I claim is:

1. An antenna array comprising:

a support;

at least three spaced-apart, electrically continuous antenna elements mounted on said support,

said antenna elements being parallel to one another, within the same plane, and spaced apart substantially $\lambda/4$ of the operating frequency of the antenna array;

an inductance element substantially resonant at the operating frequency of the antenna array,

said inductance element being generally U-shaped with parallel limbs perpendicular to said antenna elements and disposed symmetrically about the center one of said antenna elements in a plane parallel to and closely spaced therefrom;

lead-in coupling means on said inductance element; and

transmission line means coupled to said lead-in coupling means for delivering a signal to a receiver,

said lead-in coupling means being located at a position on said inductance element where the impedance of the inductance element matches the characteristic impedance of the transmission line means.

2. An antenna array comprising:

a support;

at least three spaced-apart, electrically-continuous antenna elements mounted on said support,

said antenna elements being parallel to one another, within the same plane, and spaced apart substantially $\lambda/4$ of the operating frequency of the antenna array;

an inductance element substantially resonant at the operating frequency of the antenna array,

said inductance element being in the form of an elongated loop with parallel longitudinal limbs perpendicular to said antenna elements and disposed symmetrically about the center one of said antenna elements in a plane parallel to and closely spaced therefrom;

capacitive lead-in coupling means on said inductance element; and

transmission line means coupled to said capacitive lead-in coupling means for delivering a signal to a receiver,

said capacitive lead-in coupling means being located at a position on said inductance element where the impedance of the inductance element matches the characteristic impedance of said transmission line means.

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U.S. Cl. X.R.

343—856, 861