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[54] HELICAL COIL COUPLED TO A LIVE TREE TO PROVIDE A RADIATING ANTENNA

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy**

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[52] **U.S. Cl.** **343/720**, 343/895

[51] **Int. Cl.** **H01q 1/36**

[58] **Field of Search** 343/718, 720, 856, 895, 908

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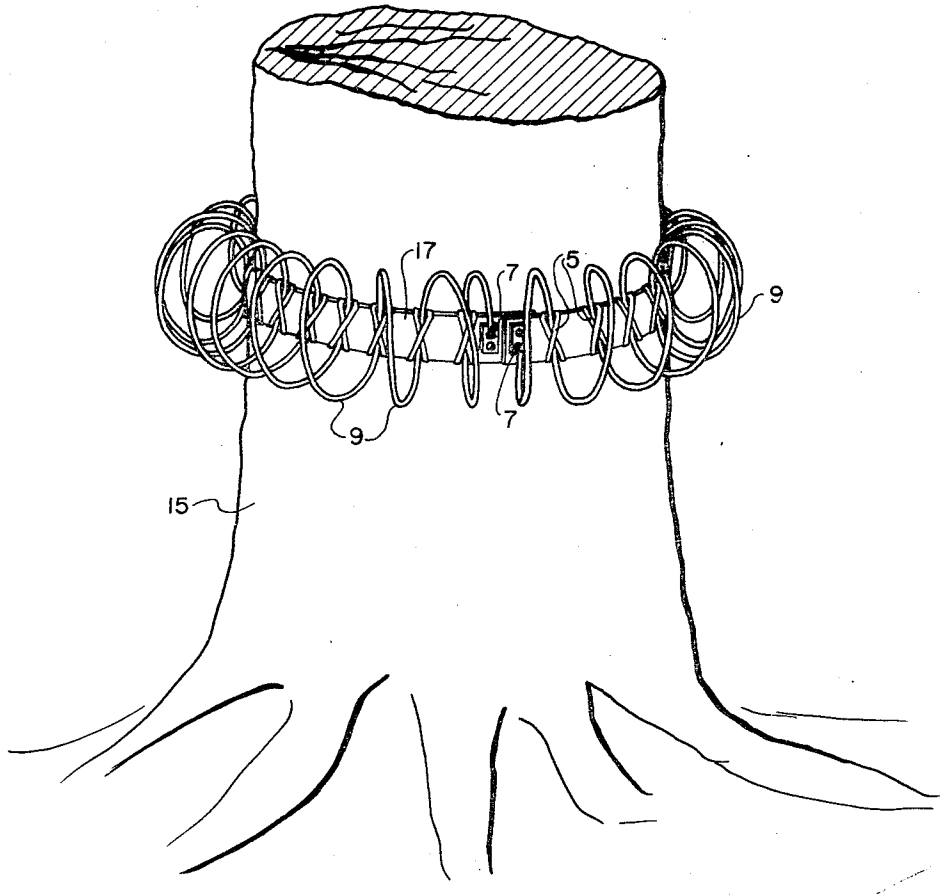
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[57] **ABSTRACT**

This device is an air-cored toroidal coil having dimensions much less than the wavelength of the applied frequency. It may be used as an omnidirectional antenna or as a coupler for converting a much larger object, such as a forest, into a giant antenna.

4 Claims, 7 Drawing Figures



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FIG. 1

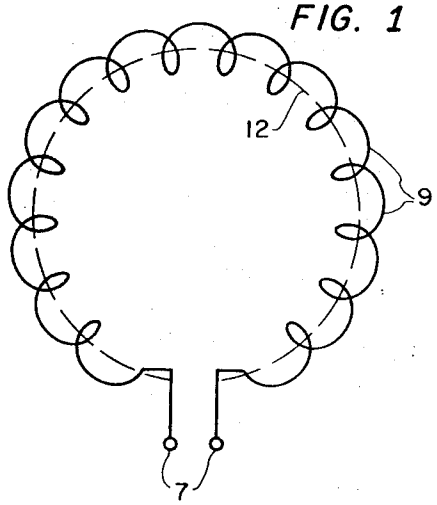


FIG. 2

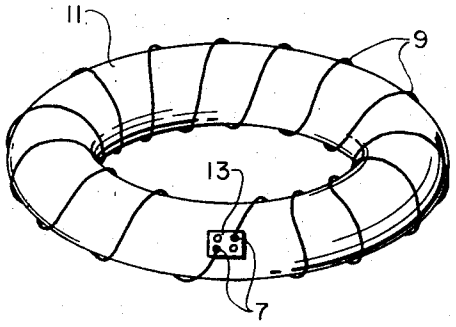
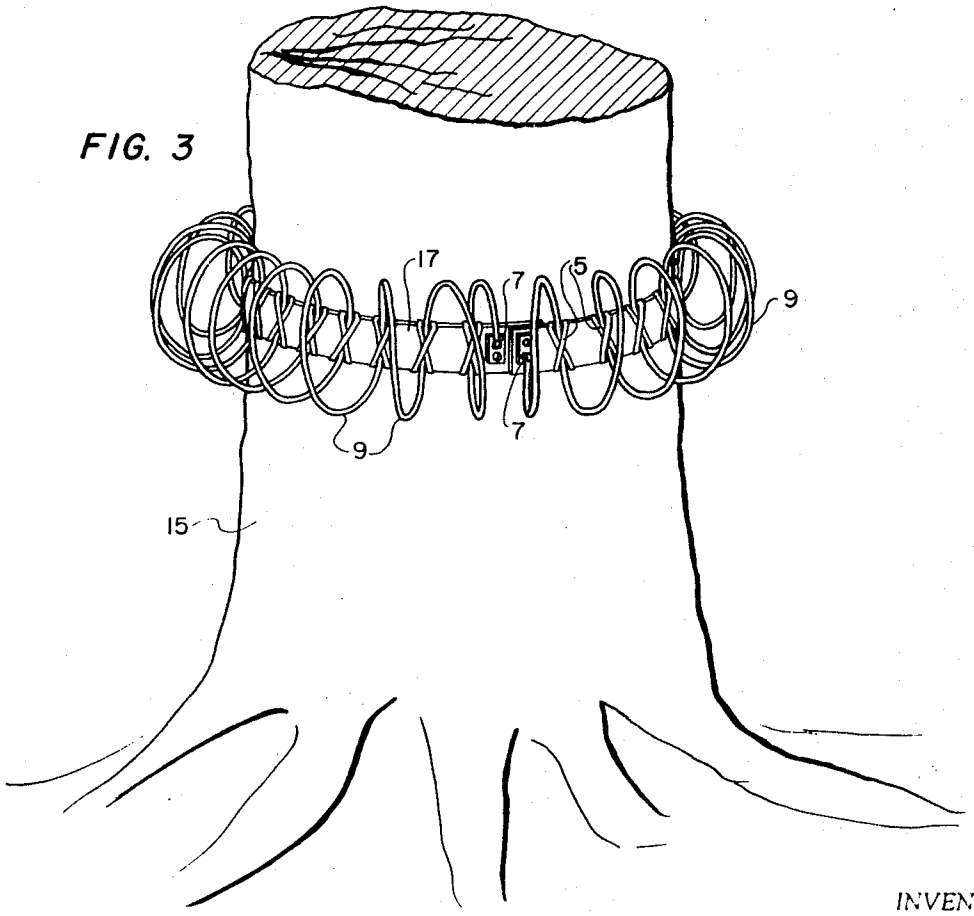


FIG. 3



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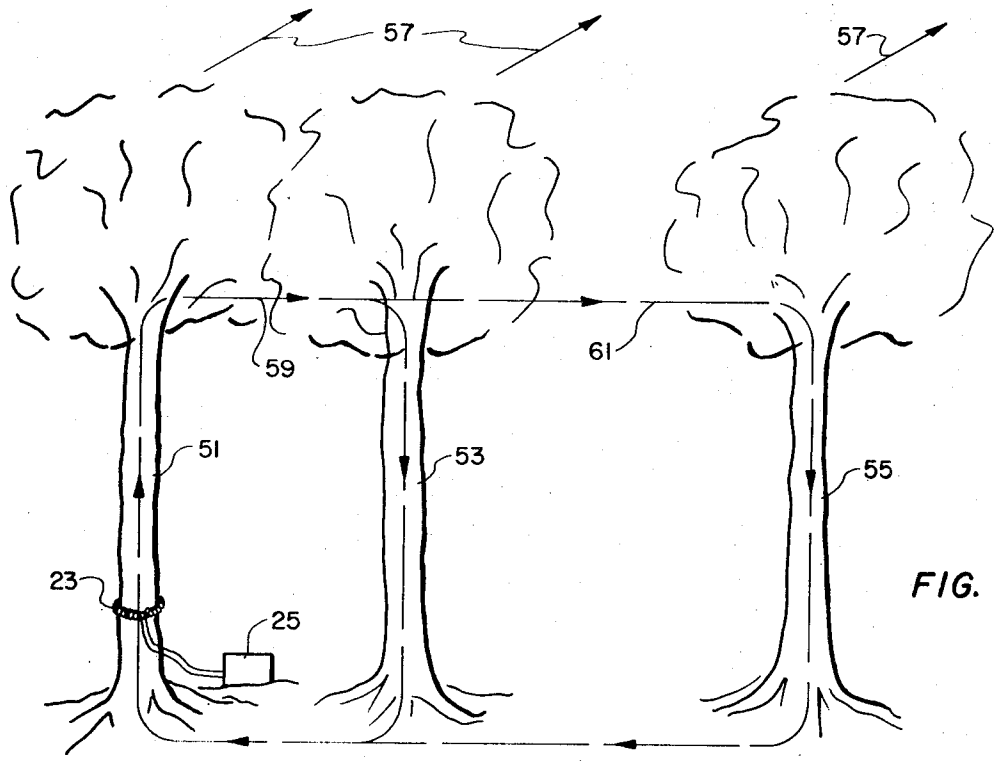


FIG. 7

FIG. 4

HEMAC TRANSMITTING LOCATIONS	ORIENTATION OF RECEIVE ANT.		RECEIVING ANTENNA TYPE (Signal to Noise Ratios)		
	$\theta°$	ϕ	WHIP	HEMAC	LOOP
In clear, 2' above ground surface, D=30'	0	—	26	34	9
	90	0	—	—	9
	90	90	—	29	20
In bush with whip, D=3'	0	—	22	44	10
	90	0	26	42	8
	90	90	26	42	16
Around tree	0	—	29	45	9
	90	0	—	41	8
	90	90	—	41	24
In clear, 2' above ground surface, D=6'	0	—	45	37	15
	90	0	—	31	18
	90	90	—	32	25

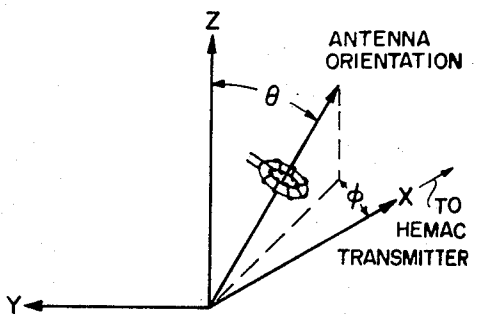


FIG. 5

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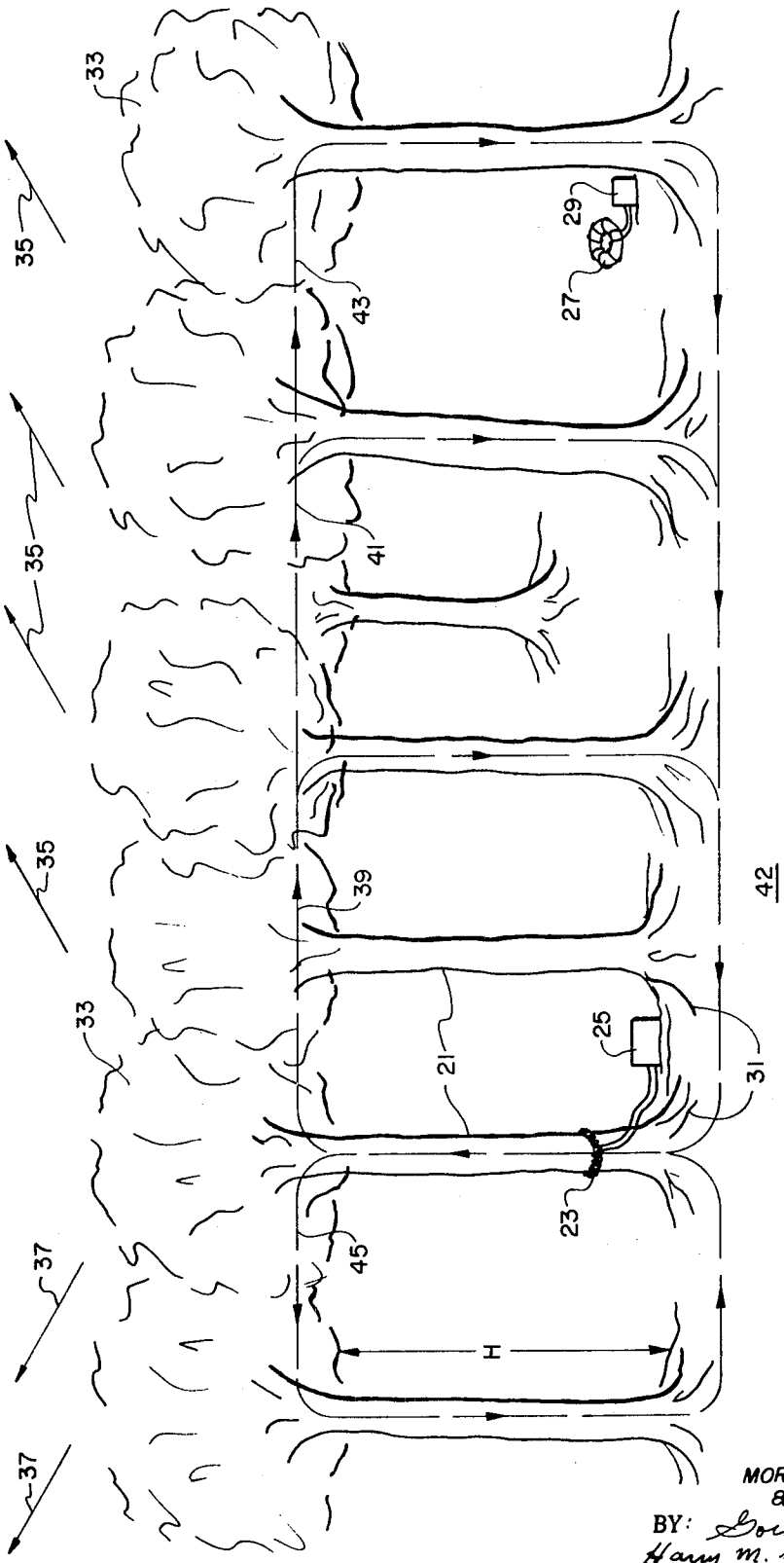


FIG. 6

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HELICAL COIL COUPLED TO A LIVE TREE TO PROVIDE A RADIATING ANTENNA

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to use of any royalty thereon.

The present invention relates to a novel and useful antenna and coupler and a communication system including it, and more specifically to a novel device of this type which includes in one device the advantageous features of a plurality of prior art devices. The HEMAC comprises in effect an air-cored toroidal coil. Alternately it may be described as a helical antenna with its axis bent into a circular shape or a loop. In addition, it differs from a conventional helical antenna in that its dimensions are all very much smaller than the wavelength of its operating frequency. The present device may function as an antenna for directly radiating energy from a transmitter to free space or directly picking up and applying signals to a receiver, or it may function as a coupler for coupling a transmitter or receiver to a larger radiator. In this latter function the HEMAC has been found to be very effective in coupling a high frequency (HF) radio set to a natural radiator comprising a forest. The HEMAC coupler was wrapped around a tree trunk. The applied frequency was such that the space between the forest floor or ground and the overhead foliage comprising the interleaved crowns of the trees was approximately the required dimension to form a sort of waveguide or cavity for directing the energy from the HEMAC through the treetops into the airspace above. The conductivity of the foliage and the earth is of course much less than that of the metals of which conventional waveguides are constructed and hence the forest energized by the HEMAC is more analogous to a "leaky" waveguide. The energy which leaks from the treetops is propagated through the air and can be received by remote conventional antennas in the open, or by a similar HEMAC receiving system in a remote forest or jungle. The energy which is directed through the forest may be received by a remote HEMAC system. The forest may be converted to an omnidirectional or directional radiator, depending on the location of the HEMAC therein.

The HEMAC also has other advantages and applications. It combines the certain advantageous features of conventional loop and whip antennas and it is omnidirectional as well as omnipolarized. Thus a signal radiated by a HEMAC can be picked up by a whip or loop antenna regardless of the orientation of the whip or loop. This results from the fact that no matter which direction the HEMAC is viewed from, some part of it will be carrying current across the line of the observer's sight and the radiation from this part will be propagated toward the observer. Since a whip produces mainly an electric field and loop mainly a magnetic field and since the HEMAC produces both electric and magnetic fields polarized in all directions, the term "hybrid electric-magnetic" has been applied to this combination antenna and coupler. Further the HEMAC can be parasitically excited by a conventional antenna adjacent thereto or conversely an adjacent conventional antenna may be excited by an active HEMAC in the vicinity.

The toroidal HEMAC may comprise a plurality of self-supporting turns attached to a belt provided with fastening means whereby it can be easily strapped around a tree trunk, or it may be wound on and supported by a toroidal surface such as an inflated inner tube or foam plastic toroid.

It is thus an object of this invention to provide an improved omnidirectional untuned antenna.

It is another object of this invention to provide a coupler capable of converting a forest or jungle into a giant antenna.

A further object of the invention is to provide a communications system useful for transmitting signals from locations within jungles and forests to areas outside and inside thereof and for receiving signals from said areas.

Another object of the invention is to couple radiofrequency energy to a forest or jungle in such a way that a major portion of the coupled energy is radiated into space from the foliage overlying the forest or jungle.

A further object of the invention is to provide an antenna or coupler adapted to surround a tree trunk in a forest or jungle and to couple radiofrequency energy to said tree and to the natural duct formed by the underside of the tree crowns above and the forest or jungle ground below.

A still further object of the invention is to provide an omnidirectional antenna comprising a helical antenna with its axis bent into a loop.

A further object of the invention is to provide an antenna comprising an air-cored toroid.

These and other objects and advantages of the invention will become apparent from the following detailed description and drawings, in which:

FIG. 1 is a schematic diagram of the hybrid electric-magnetic antenna and coupler (HEMAC); and

FIGS. 2 and 3 are pictorial diagrams thereof.

FIG. 4 is a table showing the performance of the HEMAC compared to other conventional antennas;

FIG. 5 illustrates the orientation of the HEMAC relative to the receiving antennas used to take the data of FIG. 4;

FIG. 6 shows how the HEMAC can be arranged to couple a radio set or transceiver to a forest or jungle in such a way that energy is radiated omnidirectionally from the treetops, and conversely incoming energy reaches the transceiver via the treetops and the HEMAC, which in this system is functioning as a coupler.

In the illustration of FIG. 7, the HEMAC and trees are arranged to form a directional antenna.

The schematic of FIG. 1 shows the HEMAC as comprising a 12-turn helix with the axis thereof, 12, bent into a circular shape so that the opposite ends of the helix are adjacent to form the antenna and coupler terminals 7. The helix is of course composed of conductive wire and can be made self-supporting by utilizing stiff wire to form the helix or it can be wound on some sort of supporting toroidal form. FIG. 2 shows a HEMAC wound on an inflated truck tire inner tube 11. The helix contains 12 turns, 9, and the two ends terminate on an insulated terminal block 13, on which the terminals 7 are mounted. The inner tube 11 of FIG. 2 is a size 7.50×15 which has an inside diameter of approximately 15 inches and an overall outer diameter of approximately 29 inches, the tube and the turns of the helix itself being approximately 8 inches in diameter. It can be seen that the 12 turns of the helix result in a rather larger, open pitch. This large pitch, together with the absence of any magnetic material associated with the HEMAC, results in a magnetically "leaky" toroid. This feature is an advantage especially when the HEMAC is used as a coupler for energizing a forest or jungle area. Ordinary toroid coils, for instance inductor coils or computer memory coils are usually designed to confine the magnetic field to the toroid interior with the use of closely wound coils and high-permeability cores, however, such features would not be desirable in an antenna, since the object of an antenna is to radiate as much energy as possible. The inner tube support for the helix of FIG. 2 made a convenient assembly for testing purpose, however in actual field use a less vulnerable support would be preferrable, for example, a foam plastic toroid. The supporting toroid should have have no magnetic properties and should have a dielectric constant as close to air as possible. That is, the relative permeabilities and dielectric constants should be as close to unit as possible. Such a rigid support or form is electrically the equivalent of air and hence and helix thereon can be considered air-cored. These features, combined with the large pitch of the helix turns results in the desired "leaky" magnetic structure, and when used as a coupler surrounding a tree trunk prevents undue concentration of the magnetic or electric fields, which would otherwise cause undue losses in the adjacent flora.

The HEMAC is highly efficient in the lower part of the high frequency band where the wavelengths are 50 meters or more. Thus, it can be seen the HEMAC has dimensions which are only a small fraction of the applied wavelength, however the forest or jungle area which can be energized by the HEMAC

has dimensions comparable to a quarter of the applied wavelength.

FIG. 3 shows a HEMAC comprising a toroid coil of approximately 30 turns, 9, mounted on a tree trunk 15 by means of a flexible belt 17. The belt may be made of leather or of the webbed fabric used as belts by soldiers. The turns of the helix or toroid 9 are self-supporting, the innermost portion of each turn thereof being attached to the belt 17, for example, by means of tape 5. The turns 9 can be made self-supporting, for example, by forming the helix from stiff steel music wire, over which a braided copper jacket is placed. Also, a stiff plastic tubing may be used, with copper Litz wire within the tubing. Opposite ends of the helix are connected to terminals 7. The overlapping portions of the belt 17 include a fastening means, such as snaps or a Velcro fastener, which is not visible in FIG. 2, but permits the coupler to be quickly mounted on or removed from a tree trunk and also permits the HEMAC to accommodate trees of varying circumference.

The number of HEMAC turns and the turn diameter can be varied to accommodate different frequencies and transmitter powers. Generally, higher frequency requires fewer turns, and higher power, greater turn diameter, so that the power density does not become excessive and cause undue dielectric losses within the adjacent flora. The HEMAC may form part of a resonant circuit, together with certain matching components within the transmitter connected thereto.

FIGS. 4 and 5 illustrate results of actual tests of the HEMAC used as a transmitting antenna in four different positions, indicated in the first column. Signal-to-noise ratios were recorded for three types of receiving antennas, namely, a whip, a HEMAC, and a conventional loop. It should be noted that the HEMAC receiving antenna shows consistently high signal-to-noise ratios regardless of the position or distance of the transmitting HEMAC and regardless of the orientation of the receiving HEMAC. On the other hand, the loop antenna maximum signal-to-noise ratio is lower than lowest similar figures for the HEMAC and in addition the loop is highly sensitive to orientation. This is to be expected since a loop antenna exhibits a null when the plane of the loop is normal to the direction of wave propagation and in fact this feature is utilized in loop-type radio direction finder antennas to determine the relative bearing of a remote transmitter. As indicated above, no matter what the orientation of the HEMAC, at least one of the loops or turns of its helix will be in position to respond to the magnetic field of an incoming wave, and by reciprocity, an applied radio signal will be transmitted in all directions.

FIG. 6 illustrates how the HEMAC can be used to couple a HF radio set to a forest or jungle. The forest of FIG. 6 comprises trees 21 with their crowns 33 interleaved to form a canopy. The root systems, 31, of the trees are also seen to be interleaved, so that the tree trunks, the tree crowns, the soil and roots form a plurality of loops around which current can flow. These loops are indicated by the reference numerals 39, 41, 43 and 45. A HEMAC 23 similar to that of FIG. 3 surrounds one of the tree trunks and is connected to a radio set or transceiver 25. The conductivity of the loops will depend on several factors. Assuming the trees are in bloom, the sap thereof carries moisture and nutrients from the ground 42 via the root systems 31 and trunks to the leaves or foliage comprising the crowns 33. The sap flows in the outer ring of the tree, just under the bark. The inner layers or rings of the trunk are relatively dry and of relatively low conductivity compared to the sap-bearing outer ring. The conductivity of the tree crowns will depend on the density of the foliage and its moisture and sap content. The conductivity of the forest or jungle floor or ground 41 will depend on the moisture content and the character of the soil, for example, dry, sandy soil would be less conductive than moist soil containing decayed organic matter. However, even in sandy soil, the interleaved root systems provide a measure of conductivity. The HEMAC 23 surrounding one of the tree trunks comprises in effect the primary of a transformer, with each of the loops 39, 41, 43 and 45 comprising secondaries, through which RF currents will flow. If the RF is in the lower part of the high frequency band where the wavelengths are of the order 60–80 meters, the quarter wavelength is 15–20 meters and this figure is equal to the distance between the forest floor 41 and the underside of the tree crowns for many typical forests. This distance is indicated as H in FIG. 6. Thus, this space under the tree crowns can act as a giant resonant cavity or waveguide.

The arrows on the loops 39, etc., indicate the direction of current flow therein. Thus all of the loops to one side of the HEMAC coupler 23 have currents flowing toward the right or away from the HEMAC while the current in loop 45 on the opposite side of the HEMAC flows toward the left. During the opposite half of the RF cycle, of course, all of these currents will be reversed. The portion of the energy not trapped and ducted through the forest is radiated from the treetops since the conductivity thereof is generally not nearly that of metal and further there are gaps or holes in the foliage through which energy can leak in the manner of a leaky waveguide, as mentioned above. The arrows 35 and 37 indicate the direction of propagation of this energy. It is launched generally upward and away from the HEMAC coupler. Thus, if the HEMAC 23 is mounted on a tree trunk which is at the center of a forest or jungle, the radiation from the treetops will be omnidirectional.

If the HEMAC is mounted on a tree which is at the end of a line of trees, as in FIG. 7, the radiation will be concentrated in a direction away from the HEMAC along the line of trees, as indicated by the arrows 57. Thus a directional antenna can be formed.

In explaining the mode of operation of this invention, some other analogies in addition to the leaky waveguide analogy mentioned above may be useful. For example, the HEMAC mounted on a tree may be thought of as a large whip antenna, the tree trunk comprising the whip, the foliage top-loading capacity, and the root system and the earth to which it is conductivity connected forms the ground or counterpoise for the whip.

The HEMAC 27 and transceiver 29 lying on the forest ground would be used where it is desired to confine as much energy as possible to the forest duct. In this case most of the energy would be confined to the airspace or duct between the overlying tree foliage and the ground, which, as noted above, has the proper dimensions to form a giant waveguide in the HF region. This type of system would be used where it is desired to communicate with another similar remote station located in the same jungle or forest.

While the invention has been described in connection with specific illustrative embodiments, variations thereof will be apparent to those skilled in the art. Hence, the scope of the invention should be limited only by the appended claims.

What is claimed is:

1. In combination with the trunk of a live tree of a forest in which the crowns of the trees are interleaved to define a duct or airspace between the earth and the underside of the foliage of said crowns, an air-cored toroid coil girdling said tree trunk, said toroid coil comprising a self supporting helical coil, a nonconducting nonmagnetic flexible belt, each coil turn being attached to said belt with the belt exterior to the helical coil and of a width which is a minor fraction of the circumference of the coil turns, terminals connected to the respective ends of the helical coil at the ends of the belt, fastening means at the ends of the belt for securing said helical coil in place as a toroid coil around said tree trunk, all of the coil turns being spaced apart so that the turns do not abut when the coil is in place around said tree trunk, and a radio set connected to said terminals.

2. The combination of claim 1 wherein said tree is at one end of a line of trees to direct rf radiation along said line of trees away from said air-cored toroid coil.

3. A self-supporting helical coil, a nonconducting nonmagnetic flexible belt, each coil turn being attached to said belt with the belt exterior to the coil, said belt being of a width which is a minor fraction of the circumference of the coil, ter-

minals connected to the respective ends of said helical coil at the ends of the belt, and fastening means at the ends of said belt whereby said coil may be easily strapped around a tree trunk, all of said coil turns being spaced apart so that the turns do not abut when the coil is strapped around a tree.

4. The coil of claim 3 wherein the diameter of each helical turn is approximately 1 foot and the number of turns is approximately 30.

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