SURFACE-WAVE ANTENNA HAVING DISCONTINUOUS COAXIAL LINE

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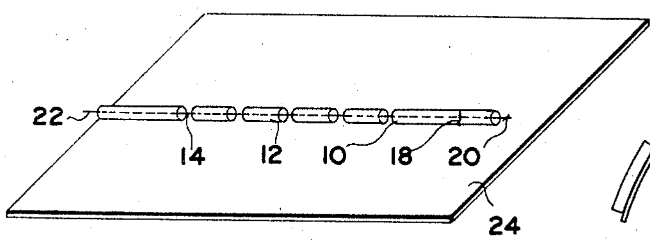

FIG. 1

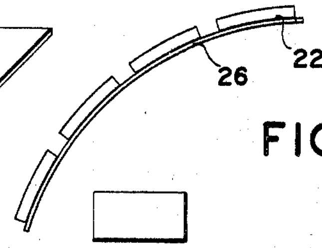

FIG. 1B

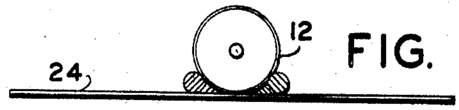

FIG. 1A

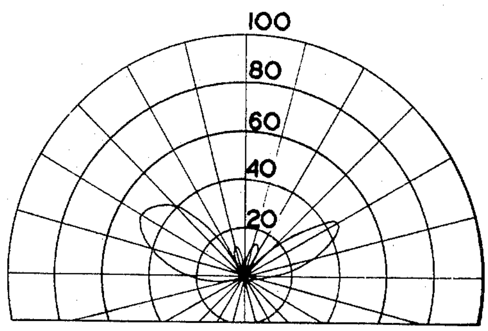

FIG. 3

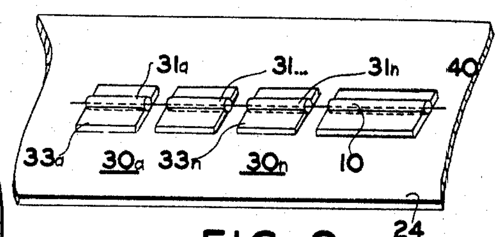

FIG. 2

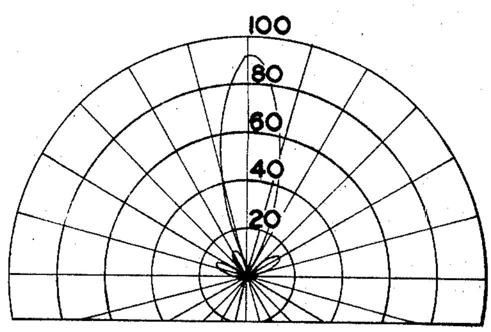

FIG. 4

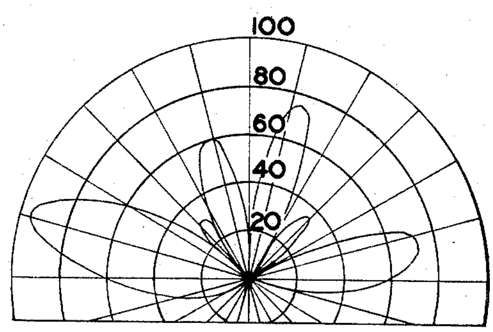

FIG. 5

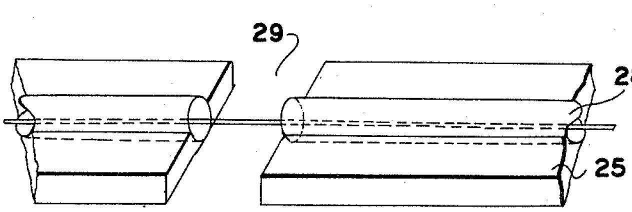

FIG. 2A

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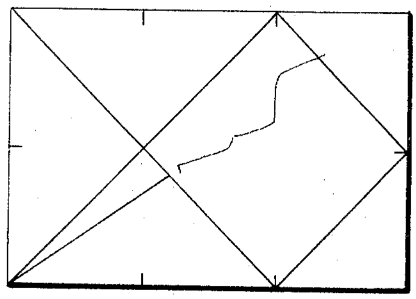

FIG. 6

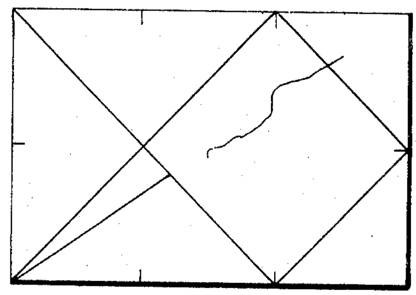

FIG. 7

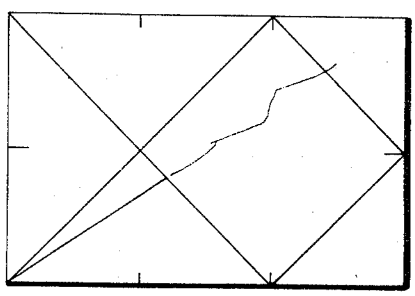

FIG. 8

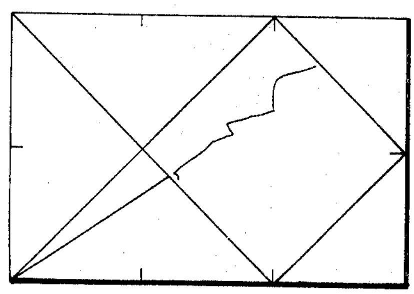

FIG. 9

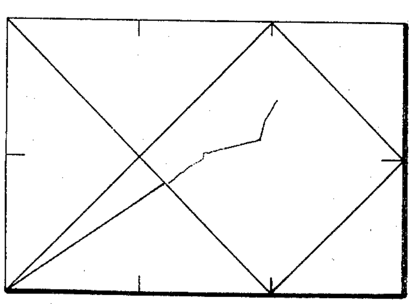

FIG. 10

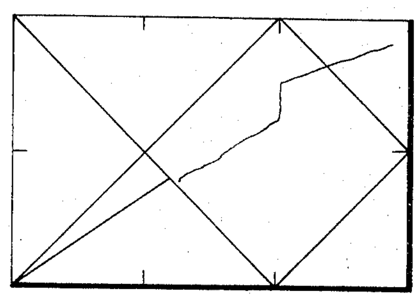

FIG. 11

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SURFACE-WAVE ANTENNA HAVING DISCONTINUOUS COAXIAL LINE

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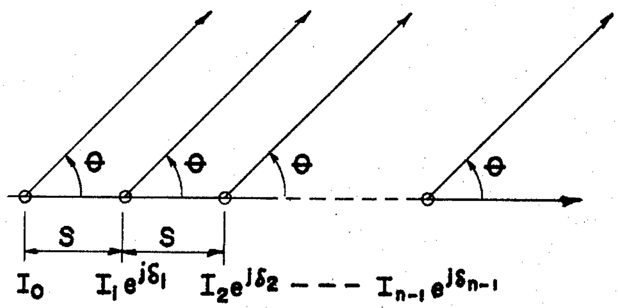

FIG. 12

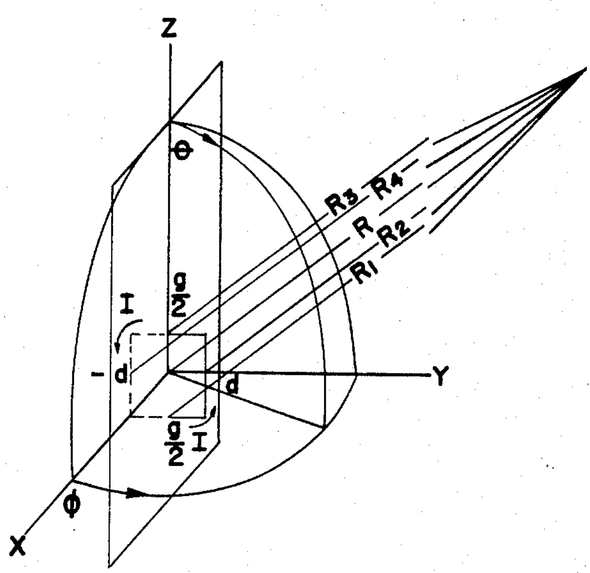

FIG. 12(A)

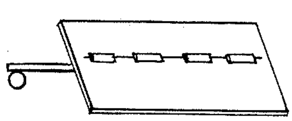

FIG. 12(B)

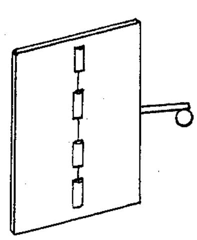

FIG. 12(C)

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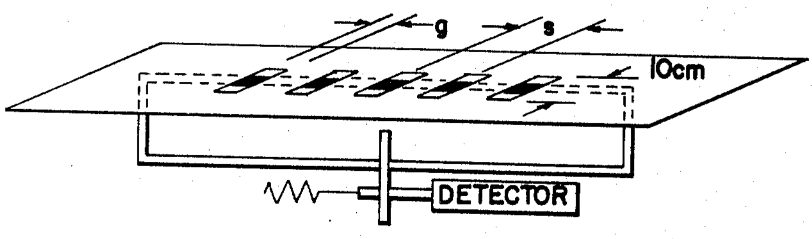

FIG. 13

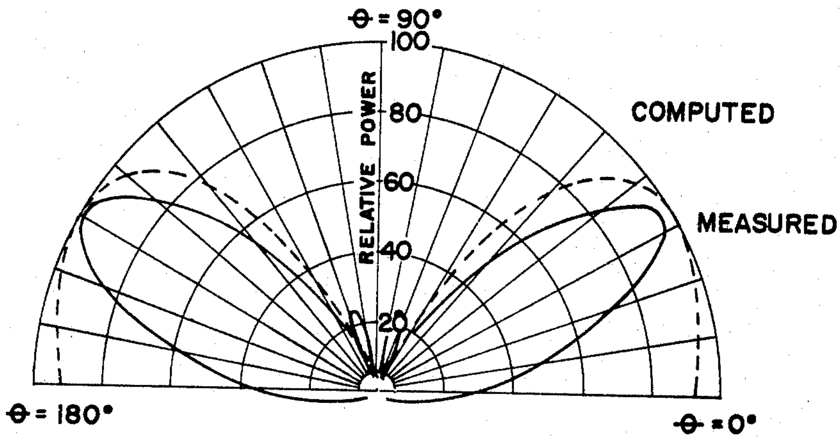

FIG. 14

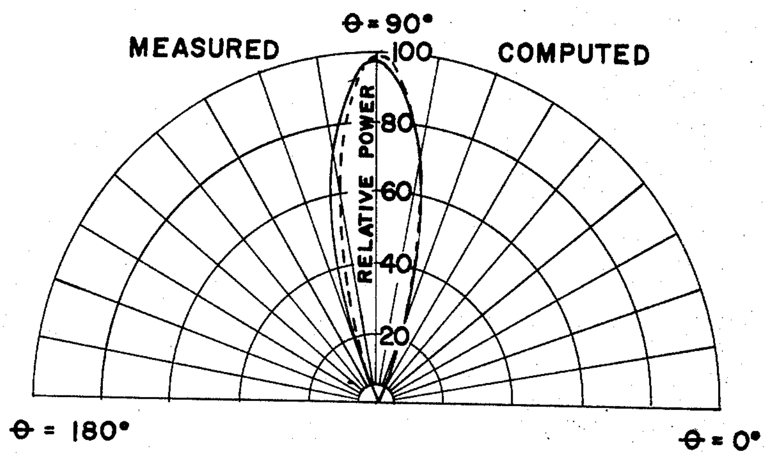

FIG. 15

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SURFACE-WAVE ANTENNA HAVING DISCONTINUOUS COAXIAL LINE

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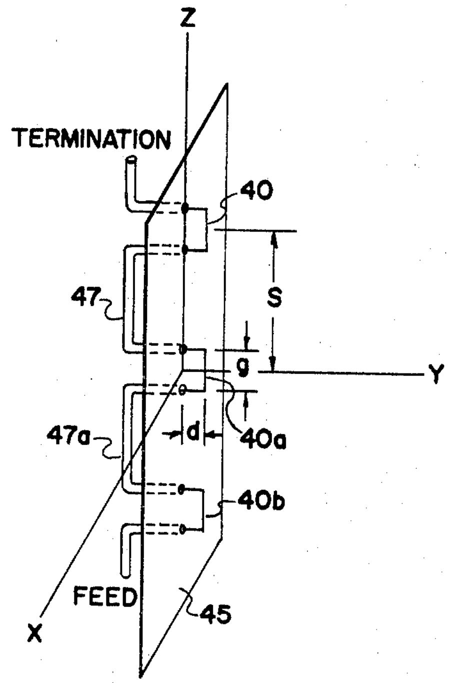

FIG. 16

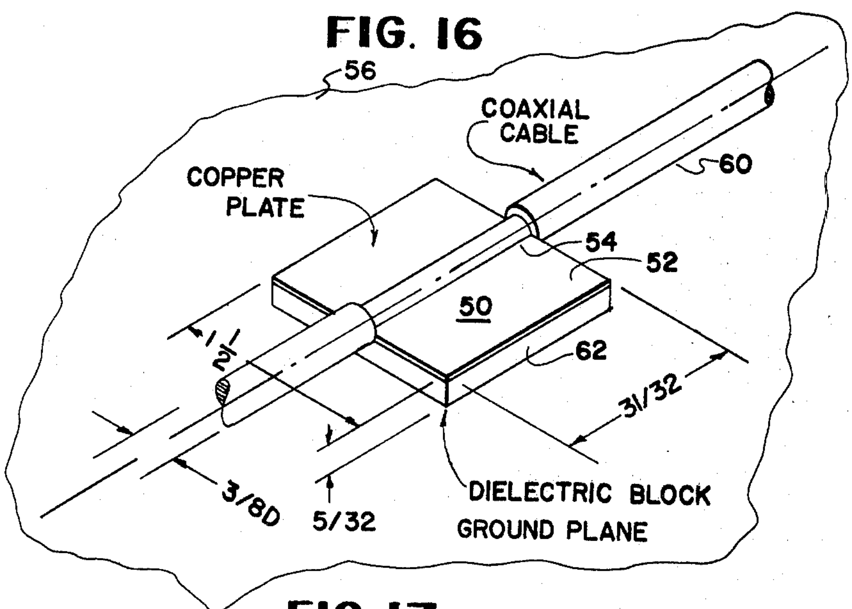

FIG. 17

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3,480,961

SURFACE-WAVE ANTENNA HAVING DISCONTINUOUS COAXIAL LINE

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Int. Cl. H01q 3/00
U.S. Cl. 343—765 4 Claims

ABSTRACT OF THE DISCLOSURE

The invention is for an integrated TEM-line antenna and particularly relates to a traveling-wave antenna integrally formed into a surface wave ground plane of a uniformly-periodic slow-wave structure capable of scanning with frequency one or more beams from the backfire direction to the endfire direction. In a preferred embodiment the antenna is a current sensitive array comprising a periodically interrupted coaxial transmission line bonded to a metal ground plane. The antenna is fed at one end of the line and terminated at the opposite end. The termination influences the number of traveling waves on the line, and hence the number of scanning beams in the far-field pattern. Other configurations of the invention result in alternative current or voltage sensitive arrays and arrays shortened in overall length.

BACKGROUND

In a most general aspect a transmission line—such as a two-wire line—will propagate energy in free space. To achieve transmission of maximum energy at a given frequency, control the directivity of the radiated beam, and to control the shape of the radiated beam, many physical modifications of the two-wire line have been disclosed in the prior art. The most basic of these configurations is the traveling-wave two-wire type of structure. There are many prior patents and much literature on this type of antenna, and a review thereof is not necessary. It will suffice for an understanding of the present invention to describe the fundamental concept as a structure having an inner and outer conductor, discontinuities evenly spaced (in most instances a half-wave apart, one end terminated, and the other end having electromagnetic energy fed thereto. In operation of this antenna traveling-wave currents will progress from the energy source along the inner conductor until terminated at the opposite end-thereby setting up standing waves in the outer conductor. Energy is radiated at the discontinuities. The radiated beam in this type of two-wire traveling wave antenna will be 360° with respect to its transverse direction. That is, most of these antennas exhibit broadside propagation. The shape and size of the beam is dependent on the spacings of the discontinuities, the frequency, and the number of discontinuities. Other antennas of the general two-wire traveling-wave structure could be of the slot type with radiating probes. Certain of these antennas, such as that shown in U.S. Patent No. 2,947,988, will propagate energy end fire—and specifically in this patent—will maintain a beam pattern over a range of frequencies.

Another type of antenna is that of the surface-wave structure. The literature describing this type of antenna is reviewed in U.S. Patent No. 3,108,278. However, for the purposes of the present invention, it will suffice to say that a surface structure will not propagate energy unless it has currents generated thereon. This is generally accomplished by providing a discontinuous structure.

Referring again to the traveling-wave type of antenna, the actual structure comprises an upright or vertical pole

or rod type of antenna. From a practical application—no matter how well this structure may perform electrically—the speed of present day aircraft and missils preclude its use. Even in the slower type of craft where the vertical rod type of antenna may be tolerated, its other attendant physical problems make it undesirable. The skin of the craft must be broken and extensively reinforced to support the rod. Further, the antenna must be mounted —for polarization and radiating directivity—in a certain position on the craft. Many times, because of electrical lines, fuel lines, mechanical linkages, etc., a compromise at the best must be made.

Further, in general theory of operation of the traveling-wave antenna and the surface-wave structure, placing a traveling-wave antenna adjacent to a conductive structure will disrupt the phase distribution of the currents; practically, then, shorting out the antenna and destroying its radiating capabilities.

It has been suggested, however, that a traveling wave antenna placed adjacent a surface-wave structure may not short and may generate currents in the ground. Such an expedience was tried, and although the antenna did not "short out" a practical operative embodiment was not achieved. Exactly what occurred was not appreciated at the time except there were derived no useful patterns.

Further reference is made to a German Patent No. 902,510, issued to Dallenbach. Although showing a related structure that patent does not provide a current sensitive drive, i.e., is voltage sensitive, is limited to a single frequency, and hence limited to a single radiation pattern.

SUMMARY OF INVENTION

The present invention, in its most fundamental embodiment, comprises a two-wire type of traveling-wave antenna; and again, contrary to accepted theory, is physically positioned with its longitudinal axis to a conducting surface. That is, the traveling wave is not electrically shorted out. However, in order that there may be derived a useful embodiment, the entire length of the outer conductor was electrically terminated to the surface-wave structure. Further, currents are generated in the surface structure adding to the radiating capabilities of the combined structure.

Single and dual beam versions of the slotted TEM-line antenna, results in a light weight, low profile, low-to-medium gain UHF-VHF traveling-wave antenna. The antennas can operate in frequency-scanning modes over an octave bandwidth, or in broadside modes over a 30 percent bandwidth, with typical VSWR's under 2:1.

Since it was found that the excitation coefficients of the array elements are controlled by the delay in the interconnecting lines, the antenna can be foreshortened physically when suitable electrical delay is maintained between the elements. The TEM-line antenna was foreshortened by moving the radiating elements closer together so that the interconnecting delay lines meander on the surface of the ground. Length reductions of as much as 5:1 have been achieved this way.

Finally an improved configuration of providing a capacitance at the gap results in the optimum in obtaining relatively constance impedance characteristic ν's frequency. In one orientation the antenna is a current sensitive device whereas in another the antenna is a voltage sensitive device.

As pointed out above, with respect to the difficulty in mounting antennas on the various types of aircraft, it must be further appreciated that once a particular type of structure is decided upon, and once the mounting position on the craft is chose, the polarization of the antenna is also automatically determined. With the present invention, the pole type of structure that is integrated into the skin of the ship may be oriented in any direction thereby giving a choice of polarization.

OBJECTS

It is accordingly a principal object of the present invention to provide a new and improved antenna structure that may be suitably integrated with the outer surface of the vehicle.

Another object of the invention is to combine the two-wire traveling-wave type of antenna and a surface-wave structure in a manner to control the voltage and current properties of the antenna.

A further object of the antenna of the present invention is to utilize the skin of a vehicle or aircraft as a radiating element.

Further objects and features of the present invention will become apparent from the following detailed description when taken in conjunction with the drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a typical illustration of the fundamental traveling-wave-surface-wave structure of the present invention;

FIGURE 1A is a cross-sectional side view of FIGURE 1;

FIGURE 1B is a side view of an embodiment wherein the surface-wave structure is other than planar;

FIGURE 2 illustrates a practical constructed embodiment of the present invention;

FIGURE 2A illustrates an alternative embodiment of the invention;

FIGURE 3 is a graphical illustration of the principle-plane radiation pattern of the antenna of FIGURE 2 at a low frequency;

FIGURE 4 is a graphical illustration of the principle-plane radiation pattern of the antenna of FIGURE 2 at a midfrequency.

FIGURE 5 is a graphical illustration of the principle-plane radiation pattern of the antenna of FIGURE 2 at a high frequency;

FIGURE 6 is a graphical diagram of a Brillouin curve with a 2 cm., 5-element flush antenna;

FIGURE 7 is a graphical diagram of a Brillouin curve with a 1 cm., 5-element brass housing antenna;

FIGURE 8 is a graphical diagram of a Brillouin curve with a 2 cm., 5-element brass housing antenna;

FIGURE 9 is a graphical diagram of a Brillouin curve with a 3 cm., 5-element brass housing antenna;

FIGURE 10 is a graphical diagram of a Brillouin curve with a 2 cm., 5-element slotted coaxial antenna;

FIGURE 11 is a gaphical diagram of a Brillouin curve with a 2 cm., 10-element slotted coaxial antenna;

FIGURE 12 illustrates the array factor of the TEM antenna of FIGURE 1;

FIGURE 12A illustrates the far-field of the TEM antenna of FIGURE 1;

FIGURE 12B illustrates schematically the rotation of the antenna about its Z axis;

FIGURE 12C illustrates schematically the rotation of the antenna about its X axis;

FIGURE 13 illustrates an alternative termination, i.e., hybrid junction, for the TEM antenna of FIGURE 1;

FIGURE 14 illustrates the radiation pattern of the antenna of FIGURE 1 at a first frequency;

FIGURE 15 illustrates the radiation pattern of the antenna of FIGURE 1 at a second frequency;

FIGURE 16 is a schematic representation of the TEM-line antenna having a delay line loading; and,

FIGURE 17 illustrates the capacitance radiating element of a TEM-line antenna.

DETAILED DESCRIPTION OF DRAWINGS

Referring now to FIGURES 1 and 1A there is illustrated the antenna of the present invention in its simplest

form. The coaxial line **10** is constructed to conform to a basic type of two-wire traveling-wave antenna. The overall length of the cable will be several wave lengths long at the normal operating frequency. Short gaps of the outer conductor **12** are removed to exposed the inner conductor **14** to form electrical discontinuities. The spacing between gaps approximates a half-wave length of the fundamental frequency. The end **16** is shorted or terminated in a conventional manner. Since the exact fundamental frequency may be varied, a sliding short circuit bar **18**, movable by lever **20**, is employed. Electromagnetic energy is fed at end **22**.

Operationally, the currents in the coaxial wire of FIGURE 1, if permitted to propagate in free space, would travel in a wave along the center conductor **14** from the source point **22** to the terminated end **18**. The currents would then be set up as standing waves along the outer conductor **12** thereby permitting energy to be radiated from the inner conductor **14** at its free openings.

In accordance with the present invention, the traveling-wave antenna is physically placed in longitudinal contact with the surface-wave structure **24**. The outer conductor **12** is electrically connected to the ground structure **24** along its entire length and extremely good electrically at least at the gap points.

Again, operationally, it has been found that the energy radiated by the traveling wave would not be shorted out in the surface-wave structure. To the contrary, a complete and satisfactory operable antenna is had and the currents are permitted to be propagated. It is believed that the currents normally set up in the outer conductor induce currents in the ground plane (surface-wave structue) within the area of the discontinuities. These currents, in turn, are radiated by the ground plane in this specific area.

Let β_n be the phase constant of the n^{th} mode, or space harmonic, along the structure, and k the free space phase constant, then

$$\beta_n = k \cos \theta_n \quad (1)$$

where θ_n is the beam angle. From array theory, β_n is also related to the element spacing S by

$$\beta_n = \beta_0 - \frac{2n\pi}{S} \quad (2)$$

where β_0 is the phase constant of the structure feeding the elements and $n=0\pm1, \pm2 \ldots$.

For real propagation $|\beta_n| \leq k$. Hence, from Eq. 2 the first space harmonic is at backfire when

$$\beta_1 = -k = \beta_0 - \frac{2\pi}{S} \quad (3)$$

and at endfire when

$$\beta_1 = k = \beta_0 - \frac{2\pi}{S} \quad (4)$$

Similarly, for the second space harmonic the backfire condition is

$$\beta_2 = -k = \beta_0 - \frac{4\pi}{S} \quad (5)$$

and the endfire condition is

$$\beta_2 = k = \beta_0 - \frac{4\pi}{S} \quad (6)$$

Using the above equations we can determine the range of frequencies for which only one radiating mode exists on the structure, namely, the β_1 mode. The lower bound on the β_1 mode is $\beta_1=-k$, and the upper bound is $\beta_2=-k$. From Eqs. 3 and 5 the corresponding frequency band is

$$\frac{30}{S(\sqrt{\epsilon_r}+1)}\leq f(\text{gHz.})\leq\frac{60}{S(\sqrt{\epsilon_r}+1)}$$

where ϵ_r is the relative dielectric constant of the feed structure and f (gHz.) is the frequency in gHz.

Thus, there is an octave band of frequencies for which only a single radiating mode exists.

The far-field of the TEM-line antenna consists of the product of an array factor times an element factor. The array factor may be derived with reference to FIGURE 12, which shown N isotropic elements with uniform spacing S along the X-axis, each element having a complex excitation coefficient of the form

$$I_n=|I_n|e^{j\delta_n} \tag{8}$$

For the far field, the array factor may be expressed as the magnitude of the sum field of all sources,

$$\text{Array factor}=\left|\sum_{n=0}^{N-1}|I_n|e^{j(nkS\cos\theta-\delta_n)}\right|$$

The far-field of the element may be found with the aid of FIGURE 12A which shows an electrically short rectangular current half-loop of length g and height d above an infinite ground plane. The corresponding image half-loop is shown below the ground plane.

The end-pieces of the half-loop elements at $z=\pm g/2$ are included as approximations to aid the analysis in accounting for the radiation from the y-directed components of currents flowing in complicated patterns around the mouths of the open-ended sections of the coaxial transmission lines. The error introduced by this approximation is small as evidenced by the good agreement between measured and computed patterns.

Using the usual far-field approximations for amplitude and phase terms the far electric field may be written in terms of the rectangular components as

$$\bar{E}\approx\frac{-j\omega\mu Ie^{-jkR}}{4\pi R}\left[\hat{y}\int_{-d}^{d}(e^{-jk\frac{g}{2}\cos\theta}-e^{jk\frac{g}{2}\cos\theta})dy+\hat{z}\int_{-g/2}^{g/2}(e^{jkd\sin\theta\sin\phi}-e^{-jkd\sin\theta\sin\phi})dz\right] \tag{10}$$

where $k=2\pi/\lambda$ is the free-space phase constant, and $\hat{y}$ and $\hat{z}$ are the y- and z-directed unit vectors.

However, since $d\ll\lambda\gg g/2$, the exponential terms of the integrands may be approximated by the first two terms of their power series, with the result

$$\bar{E}\approx\frac{\omega\mu Igkde^{-jkR}}{2\pi R}[\hat{z}\sin\theta\sin\phi-\hat{y}\cos\theta] \tag{11}$$

When $\hat{y}$ and $\hat{z}$ are transformed into spherical components, a more practical expression for the electric field of the single element is obtained as

$$\bar{E}\approx\frac{-\omega\mu Igkde^{-jkR}}{2\pi R}[\hat{\theta}\sin\phi+\hat{\phi}\cos\theta\cos\phi] \tag{12}$$

where $\hat{\theta}$ and $\hat{\phi}$ are the θ- and ϕ-directed unit vectors and k is the free-space propagation constant.

Referring now to FIGURE 2 there is shown a constructed embodiment of the fundamental antenna shown in FIGURE 1. The resonant sections **30***a* through **30***n* have their outer sections **31***a* through **31***n* integrally formed into the ground surface structure **40.** These outer sections, **31***a* . . . **31***n*, have an area, **33***a* . . . **33***n*, extended transverse on either side of the major direction of the traveling-wave antenna **10.** The purpose of these extended sections is to provide a broad area for electrical contact and bonding to the ground structure **24.**

As pointed out above, the antenna of the present invention readily adapts itself to a surface structure having a nonplanar configuration. With reference to FIGURE 1*b* there is shown a cross-section of the fundamental traveling-wave antenna **22** unified with a ground plane **26** having a semi-circular configuration.

Another version of the antenna that had been investigated is shown in FIGURES 2*a*. In this antenna the entire transmission line **28** was enclosed within the thickness of the ground plane **25.** The gaps **29** were in the form of transverse corrugations in the surface **25.**

As pointed out above, with respect to the conventional traveling-wave antenna, the shape and the size of the radiated beam is dependent on the number of discontinuities, the spacings of the discontinuities and the frequency. It has been found, however, that there are two distinguishing features of the antenna of the present invention which do not follow the conventional traveling-wave patterns. They are:

(1) The fundamental mode dwells over a considerable frequency interval in broadside radiation; and,

(2) The patterns taken in a direction transverse to the radiator reveal considerable unexpected detail, and the angles of maximum radiation at certain midrange frequencies are not in the principle planes of the antenna.

FIGURES 3, 4, and 5 show typical patterns obtained from a 5-element antenna constructed, as shown in FIGURE 2, at relatively low, medium, and high frequencies, respectively. The beginning of the second mode can be seen near grazing angles in FIGURE 5.

FIGURE 6 is a Brillouin or $k-B$ diagram for the corrugated surface antenna of FIGURES 2*a* with 2 cm. corrugations spaced 10 cm. apart.

FIGURE 7 is a similarly prepared Brillouin diagram for an antenna, with a 1 cm., 5-element brass housing antenna;

FIGURE 8 is a Brillouin diagram with a 2 cm., 5-element brass housing antenna;

FIGURE 9 is a Brillouin diagram with a 3 cm., 5-element brass housing antenna;

FIGURE 10 is a Brillouin diagram with a 2 cm., 5-element slotted coaxial antenna; and

FIGURE 11 is a Brillouin diagram with a 2 cm., 10-element sloted coaxial antenna.

FIGURE 6 through 11 are Brillouin diagrams drawn for various constructed embodiments of the antenna of the present invention. The Brillouin diagram was drawn by a commercial computer, using the calculated low-frequency propagation constant of the coaxial transmission line from the origin out to the edge of the first invisible region, and measured data, reduced point-by-point from the far-field patterns throughout the remainder of the frequency range covered. Specifically, it is apparent that although differing constructions were employed, all Brillouin diagrams are generally similar.

As given above, multi-beam operation of the TEM-line antenna is influenced by the termination. When the antenna is terminated in an adjustable short circuit, as in FIGURE 12, two oppositely directed traveling waves exist on the structure, hence, forward and backward beams appear in the far-field pattern. If, however, the line is terminated in a hybrid junction, as in FIGURE 13, a feedback path is provided such that energy re-enters the line in the forward direction; thus, only one beam appears in the far-field pattern. Other methods of achieving single- or dual-beam operation are given in the following table:

	Construction	Termination	No. of Beams
Antenna:			
5 FMSC	Five elements, flush mounted	Adjustable short	Two.
5 SMDF	Five elements, surface mounted	Coaxial tee with adjustable phase	Two.
10 EMSC	Ten elements, edge mounted	Adjustable short	Two.
5 FMRE	Five elements, flush mounted	Hybrid junction or isolator	One.
5 FMRE-ϕ	do	Hybrid junction with adjustable phase	One.
5 FM Z_c	do	Characteristic impedance	One.

In a specific constructed embodiment the antenna's elements are 2 cm. in length and spaced 10 cm. center-to-center. The feed structure is standard RG8/U coaxial transmission line for which $\epsilon_r=2.3$. From Eq. 7 the bandwidth for single mode (β_1) operation is (9) $1.19 \leqq f \leqq 2.38$ gHz.

The beam scanning behavior of the five-element flush mounted re-entrant termination single-beam antenna (5 FMRE) was illustrated by measured power patterns. For the five-element flush mounted short circuit termination dual-beam antenna (5 FMSC) measured power patterns are shown in FIGURES 14 and 15 together with power patterns computed from Eqs. 9 and 12. It should be noted that the computed patterns represent an array of five elements over an infinite ground plane so that some disagreement arises because of the finite ground plane of the 5 FMSC antenna. This is most apparent when the beams are near grazing as in FIGURE 9; otherwise agreement is good.

The spatial form of the main beam is suggested by the cross-section patterns of the 5 FMSC dual-beam antenna In a cross-section measured pattern at 1.704 gHz. for a look angle of 13° from broadside, the large single main beam corresponds to the direction of maximum radiation and to computer $\sin^2(\phi)$ power pattern. With the look angle at 35°, the cross-section pattern consists of two lobes, illustrating the conical shape of the main beam. A cross-section of the antenna operating in the broadside mode again resulted in the single main beam in the direction of maximum radiation.

Absolute gain measurements of the 5 FMSC dual-beam antenna operating in the broadside mode (2.04 gHz.) yielded a maximum power gain of 12.3 db±0.5 db over isotropic. Comparing this to a directivity of 23.2, computed by pattern integration techniques, the antenna is 72 percent efficient.

The voltage standing wave ratio of the 5 FMSC dual-beam antenna was measured at numerous frequencies in the range 0.8 to 2.0 gHz. using the slotted-line technique.

It has been shown that both single- and dual-beam versions of the TEM-line antenna can operate in frequency-scanning modes over an octave bandwidth, or in broadside fan-beam modes over a 30 percent bandwidth. The beam scanning similarities of both versions were most apparent when experimental results were plotted on the Brillouin diagram. The shape of the Brillouin diagram was shown to be in good agreement with theory.

Still another modification of the TEM-line elements were built and tested as shown in FIGURE 17. The radiating element **50** is essentially a transmission line formed by a small copper plate **52** above the ground plane **56**. The plate was soldered to the bottom of the center conductor **54** of the feeder transmission line **60**. The small dielectric block **62** maintains the plate **52** at the prescribed distance above the ground plane **56** while increasing the capacitance between them.

This type of construction may well represent the optimum in obtaining a relatively constant impedance characteristic versus frequency since the characteristic impedance of the feeder and TEM-line element transmission lines can be matched.

While the physical construction of this TEM-line element differs greatly from the round wire type of FIGURE 1 used in the theoretical derivations, the above developed equations still apply since the dimensions of the element are small in terms of a wavelength.

Referring against to FIGURES 12 and 12A, the TEM-line element and ground plane were rotated about the Z axis. In actual practice the structure of FIGURE 17 was rotated about its Z axis by the conventional gear arrangement shown schematically in FIGURE 12*b*. The transmitting antenna was located in the XY plane and the transmitted field was polarized parallel to this plane. Under these conditions, the TEM-lie element would radiate and thus receive a voltage proportional to

$$E_\phi=\frac{2\pi\eta D\Delta L e^{-jkr}V}{\lambda^2 r Z_0}\cos\phi \qquad (13)$$

which is essentially the characteristic shown. Note that the capacitor dipole component of the TEM-line element is the only one receiving a voltage for this orientation.

The effects of the groud plane is to tilt the main radiation lobe from the ground plane $(90°-\phi_m)$ and this can be determined approximately from

$$\sin\phi_m=1-\frac{3\lambda}{4d} \qquad (14)$$

where d is the diameter of the circular ground plane. The ratio of the radiation in the direction of the ground plane $E^2(\pi/2)$ to $E^2(\phi_m)$ is relatively independent of the size of the ground plane and given by

$$\frac{E^2(\pi/2)}{E^2(\phi_m)}=0.184 \qquad (15)$$

Patterns also were obtained with the same orientation except the transmitting antenna was rotated 90° so that its polarization was perpendicular to the XY plane. Under these conditions the voltage received by the TEM-line element is proportional to

$$E_\theta=\frac{2\pi\eta D\Delta L e^{-jkr}}{\lambda 2_r} I_c \sin\phi \qquad (16)$$

and is entirely due to the current dipole. The effects of the finite ground plane are negligible since the dipole and its image produce no radiation in its plane.

A third group of patterns were obtained by rotating the TEM-line elements and ground plane around the X axis with the transmitting antenna's polarization parallel to the ZY plane. In actual practice the structure of FIGURE 17 was rotated about its X axis by the conventional gear arrangement shown schematically in FIGURE 12C. Under these conditions the voltage received is proportional to:

$$E_\theta=\frac{2\pi\eta D\Delta L e^{-jkr}}{\lambda 2_r}\left[I_c \sin^2\theta+\frac{V}{Z_0}\cos\theta\right] \qquad (17)$$

and is a combination of the receiving characteristics of the capacitor and current dipoles of the TEM-line element. The radiation field is linearly polarized in this plane. The transmission line was properly terminated so that this voltage and current were approximately in phase. Under these conditions, the radiation from each component will add for $0\leqslant\theta\leqslant 90°$ and subtract for

$$90°\leqslant\theta\leqslant 180°$$

The relatively large concentration of radiation for $0°\leqslant\theta\leqslant 90°$ is clearly shown by the experimental patterns.

Although certain and specific embodiments are shown, departures may be made without departing from the true spirit and scope of the invention.

What is claimed is:

1. An integrated antenna comprising: an inner and outer conductor in longitudinal coaxial relationship, means for feeding electromagnetic energy at one end of said conductors, a plurality of discontinuities in said outer conductor spaced a submultiple of a wavelength of the frequency of said energy, means terminating said opposite ends of said conductors for establishing a traveling wave along said inner conductor and standing waves on said outer conductor; a surface-wave structure having an electrically conductive surface, a conductive plate, and means for joining said conductive plate to said inner conductor at said discontinuity, and said outer conductor electrically connected with said structure; whereby said traveling wave causes currents to be induced in said surface structure at said discontinuities, and means for permitting said currents to be propagated.

2. An integrated antenna as set forth in claim 1 further comprising a dielectric positioned between said conductive plate and said surface-wave structure.

3. An integrated antenna as set forth in claim 1 further comprising means for rotating said antenna thereby changing said antenna from a current sensitive radiator to a voltage sensitive radiator.

4. An integrated antenna as set forth in claim 1 wherein said rotation is in either the X, Y or the XY axis.

References Cited

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