United States Patent

Ross et al.

[15] **3,659,203**

[45] **Apr. 25, 1972**

[54] BALANCED RADIATOR SYSTEM

[72] Inventors: **Gerald F. Ross**, Lexington; **David Lamensdorf**, Cambridge, both of Mass.

[73] Assignee: **Sperry Rand Corporation**

[22] Filed: **June 15, 1970**

[21] Appl. No.: **46,079**

[52] **U.S. Cl.** **325/105,** 307/246, 325/125, 325/129, 325/152, 325/164, 325/166, 325/179, 330/20, 343/701

[51] **Int. Cl.** **H04b 1/04**

[58] **Field of Search** 325/101, 102, 106, 107, 120, 325/121, 125, 129, 160, 164, 166, 167, 169, 178, 179, 185–187, 105; 328/66–68; 333/13, 152, 4, 19, 20, 32; 343/701; 307/246

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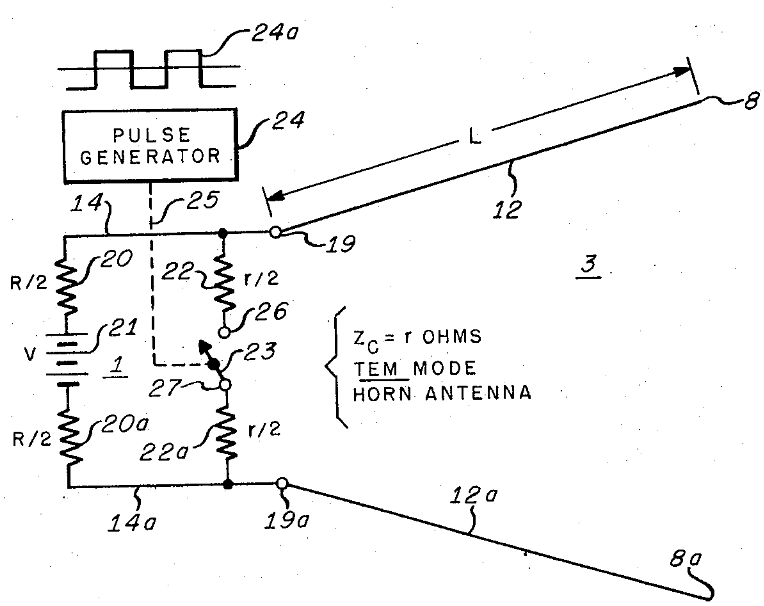
Primary Examiner—Robert L. Griffin
Assistant Examiner—Albert J. Mayer
Attorney—S. C. Yeaton

[57] **ABSTRACT**

A transmission line system for having a primarily signal-initiating section and a primarily signal-radiating section, along both of which line sections traveling electromagnetic waves may propagate without adverse interference of impedance discontinuities, is employed cyclically as an energy storage device and as an impulse radiating device having spatially directive characteristics.

13 Claims, 18 Drawing Figures



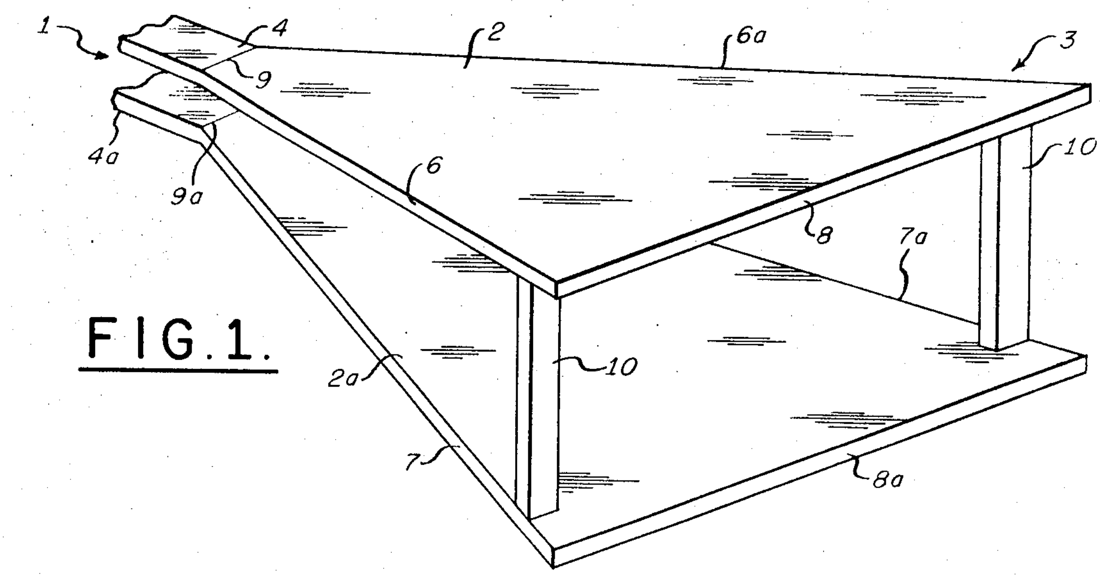


FIG. 1.

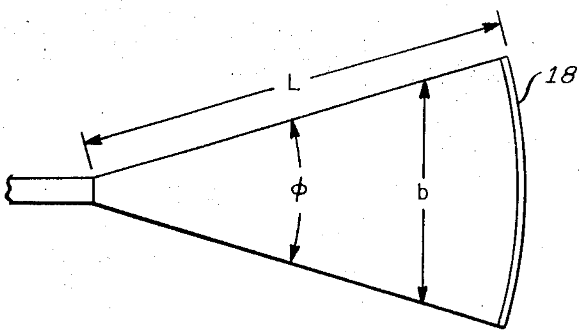


FIG. 2.

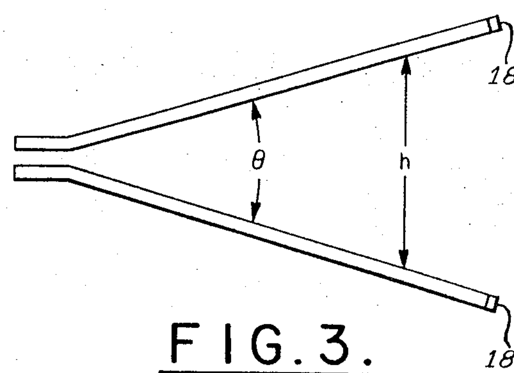


FIG. 3.

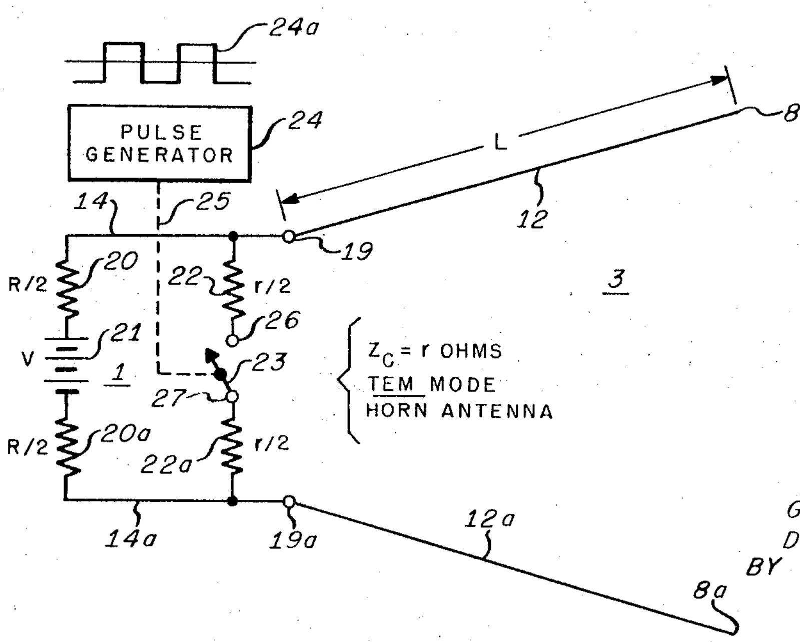


FIG. 4.

INVENTORS
GERALD F. ROSS
DAVID LAMENSDORF
BY
H P Terry
ATTORNEY

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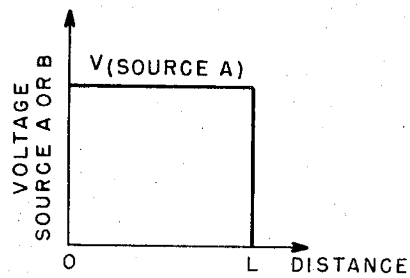

FIG. 5a.

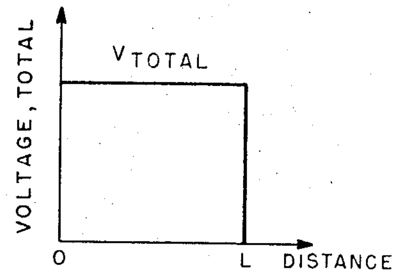

FIG. 5b.

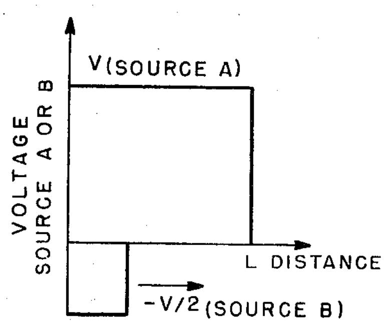

FIG. 6a.

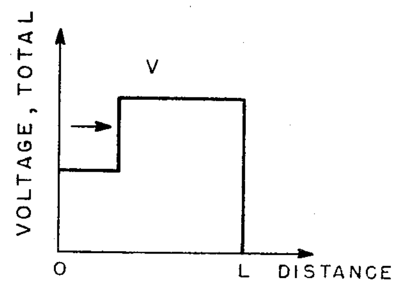

FIG. 6b.

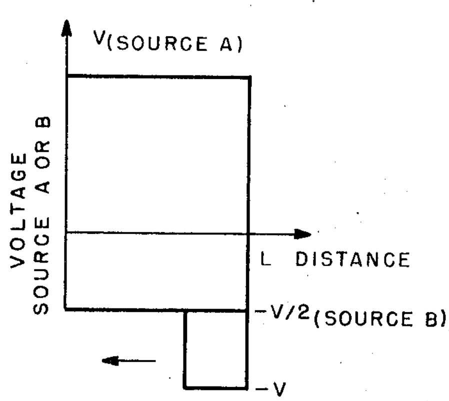

FIG. 7a.

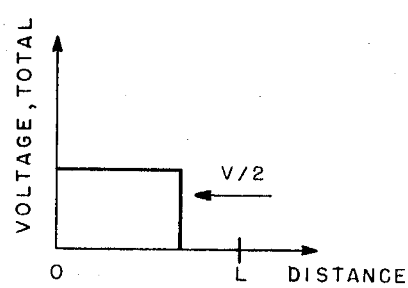

FIG. 7b.

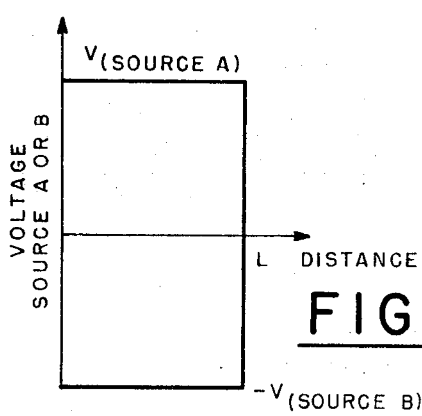

FIG. 8a.

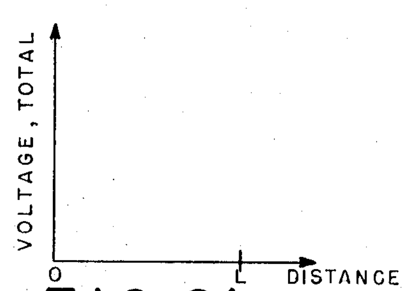

FIG. 8b.

INVENTORS
GERALD F. ROSS
DAVID LAMENSDORF
BY
HP Terry
ATTORNEY

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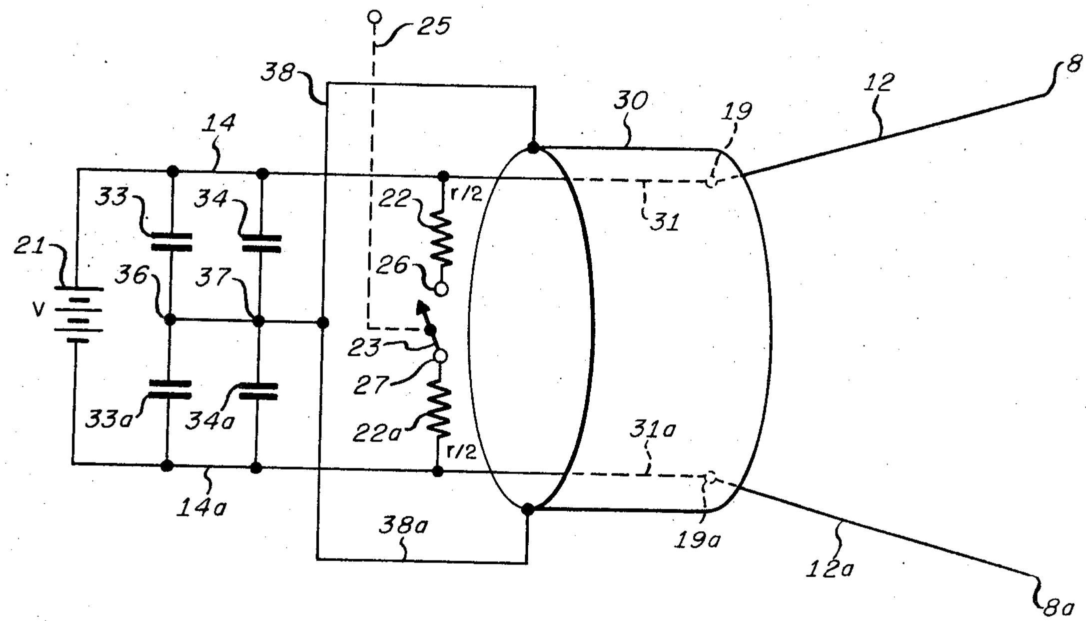

FIG. 9.

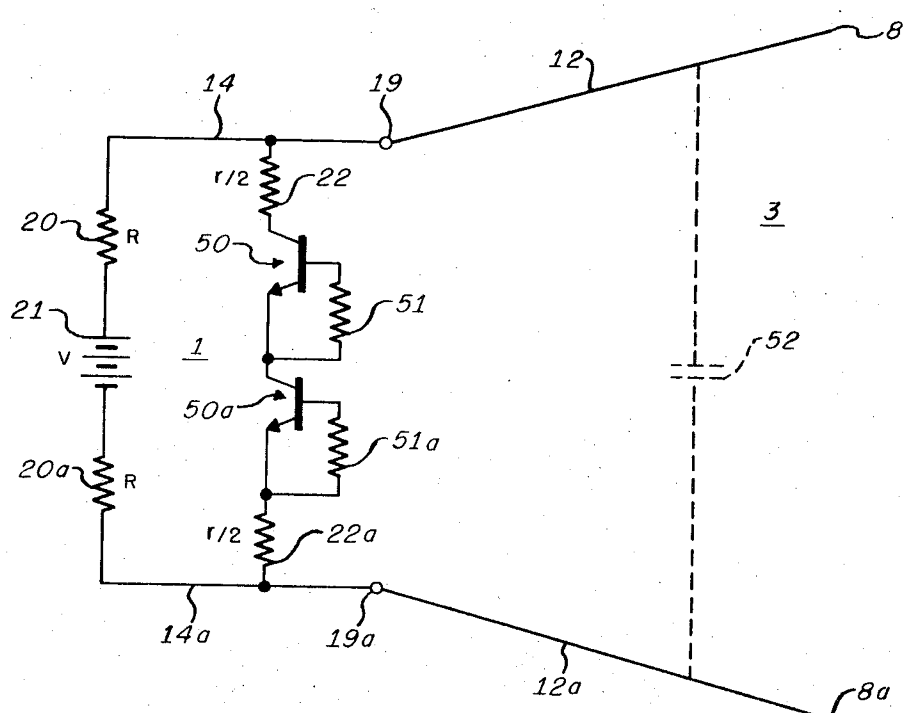

FIG. 14.

INVENTORS
GERALD F. ROSS
DAVID LAMENSDORF
BY
H P Terry
ATTORNEY

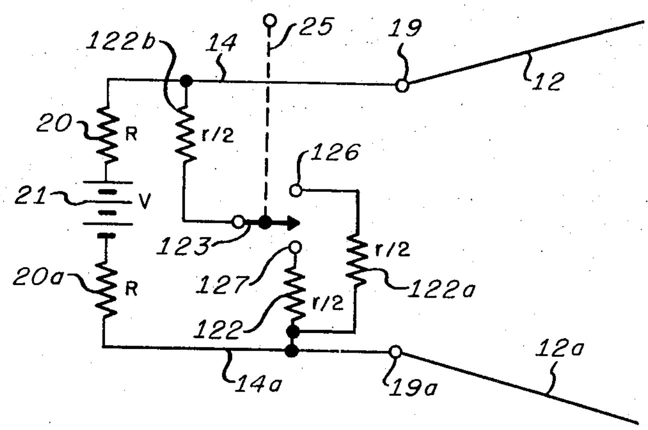

FIG.10.

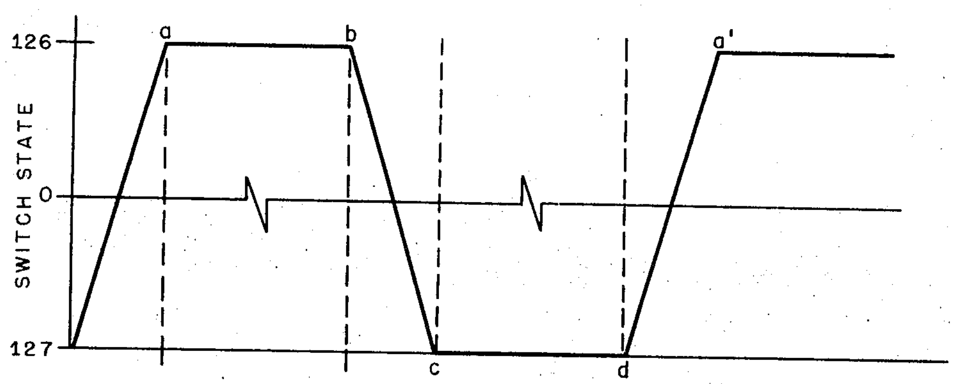

FIG.11.

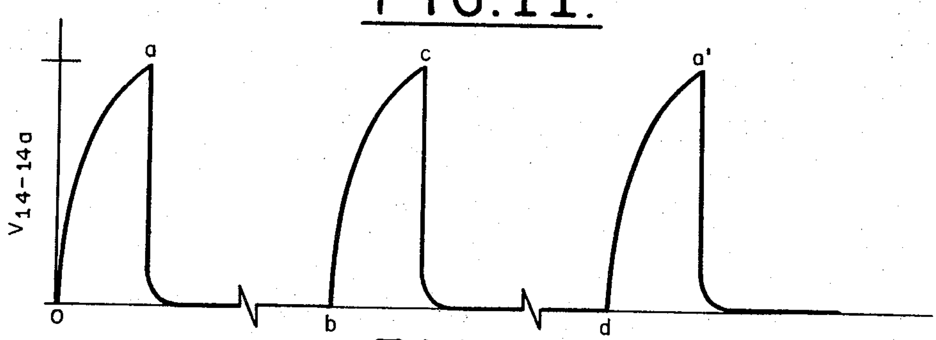

FIG.12.

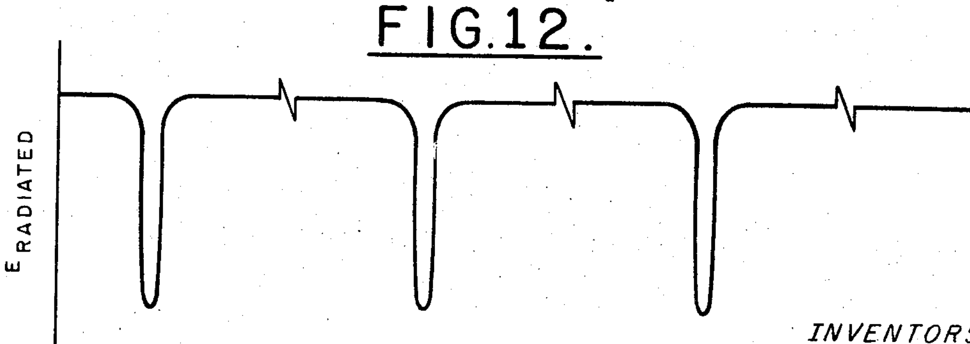

FIG.13.

INVENTORS
GERALD F. ROSS
DAVID LAMENSDORF
BY
HP Terry
ATTORNEY

BALANCED RADIATOR SYSTEM

BACKGROUND OF THE INVENTION

1. Field Of The Invention

The invention pertains to transmission line signal impulse generating and radiating means for the impulse transmission of electromagnetic energy and more particularly pertains to such signal generation and radiation elements in which constructive cooperative use is made of the elements of the system both for signal generation and for signal radiation into space.

2. Description Of The Prior Art

Known prior art antennas are not readily adaptable to the radiation or reception of sharply pulsed or stepped electromagnetic signals, even though capable of relatively broad band transmission of ordinary continuous wave signals. For example, the log-periodic array, the log-spiral antenna, and many of the known guided or surface wave antenna structures lack suitable properties for the purpose, since they present dispersive impedance discontinuities and because propagation of wave energy on or within the antenna structure is characterized by dispersive TE, TM, or other such propagation modes. Thus, the phase characteristic of the response of such antennas is not linear.

Many prior directive antennas operating in high frequency ranges have used excitation systems coupling energy to be transmitted to the radiating structure by unbalanced transmission lines. Such coupling arrangements are sometimes selected because of the relatively large size of hollow wave guides in certain frequency ranges, or because of other known considerations, including band width requirements.

However, where antennas are to be achieved yielding distortionless transmission of transient or very short pulse radiations, a design requirement is that balanced currents flow equally on either side of the driving point or the effective load of the antenna. If unbalanced currents are also permitted to flow, they decrease the efficiency of the transmitting antenna since they flow in effect to spurious loads in parallel with the desired antenna radiating load. In addition, such unbalanced currents are well known to produce time domain distortion in the field pattern of the antenna.

Baluns of various degrees of complexity are often used in the interface between unbalanced transmission lines and balanced antenna radiators, but known designs do not meet band width requirements, produce severe distortions, and often do not represent useful transitions at even moderate power levels. Many forms of such baluns do not fully prevent generation of undesirable unbalanced current flow.

Furthermore, most known antenna and associated transmitter concepts do not adapt themselves to combinations in such a manner that stepped, transient, or sharp impulse radiations are efficiently generated in a compact, inexpensive structure. In the prior art, the structure and function of the transmitter are generally fully separate from the structure and function of the antenna. Balanced transmitter-antenna configurations in which the two substantial parts of the system fully cooperate in determining the nature of the radiated signal are not possible to achieve by employing known design techniques.

SUMMARY OF THE INVENTION

The present invention relates to an improved transmitter antenna configuration employing an electrically smooth, constant impedance transmission line system for propagating TEM mode waves. The transmission line system is employed cyclically for the cooperative storage of energy on the transmission line and for its release by propagation along the transmission line for radiation at the end of a section of the transmission line formed as a flared directive antenna. Thus, cooperative use is made of the transmission line system both for signal generation by cyclically charging the transmission line at a first rate of charging and for signal radiation into space by discharge of the line in a much shorter time than for charging. Discharge of the transmission line causes a voltage wave to travel toward the open end or radiating aperture of the structure. The process operates to produce, by differentiation, an impulse that is radiated into space.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an embodiment of the antenna used in the present invention.

FIGS. **2** and **3** are respectively top and side views of the antenna of FIG. **1** and are useful in explaining its properties.

FIG. **4** is a schematic side view of the antenna of FIG. **1** showing circuit elements for exciting the antenna.

FIGS. **5***a* to **8***b* are graphs for explaining the operation of the embodiment of FIG. **4**.

FIG. **9** is a circuit arrangement alternative to that of FIG. **4**.

FIG. **10** is an improved embodiment of the circuit of FIGS. **4** and **9**.

FIGS. **11**, **12**, and **13** are graphs used in explaining the operation of the embodiments of FIG. **10**.

FIG. **14** is an embodiment of the invention whose operation is self-synchronized.

DESCRIPTION OF PREFERRED EMBODIMENT

FIGS. **1**, **2**, and **3** are illustrative of a type of balanced antenna useful in the present invention. A suitable antenna for the purpose has a wide instantaneous band width, so that it may radiate a sharp pulse or stepped signal with low distortion of the signal envelope. Further, a suitable antenna for use in the invention has an energy focusing characteristic such that energy radiated in a predetermined direction is maximum.

The modified horn antenna of FIGS. **1**, **2**, and **3** is a preferred form of an antenna having such desired characteristics. As will be seen in FIG. **1**, the antenna **3** comprises a structure having mirror image symmetry about a median plane at right angles to the direction of the vector of the electric field propagating within the antenna. The same is true of the transmission line **1**, which comprises parallel plate or slab transmission line conductors **4** and **4***a* of similar shape. Conductors **4** and **4***a* are spaced planar conductors constructed of a material capable of conducting high frequency currents with substantially no ohmic loss. Further, conductors **4** and **4***a* are so constructed and arranged as to support TEM mode propagation of high frequency energy, with the major portion of the electric field lying between conductors **4** and **4***a* and with the field substantially perpendicular to the major interior surfaces thereof. It will be understood by those skilled in the art that the term TEM mode of wave propagation is that commonly used in the high frequency literature to specify a conventional mode of electromagnetic energy propagation. In the TEM or transverse electromagnetic mode, both the electric and magnetic field components of the wave are everywhere transverse to the direction of wave propagation. This is in contrast to the character of certain other types of conventional electromagnetic waves, such as the transverse electric (TE) and transverse magnetic (TM) waves. The TE and TM modes are dispersive modes, while the TEM mode employed in the present invention is desirably non-dispersive.

The TEM modified horn antenna **3** consists of a pair flared, flat, electrically conducting planar members **2** and **2***a*. Members **2** and **2***a* are generally triangular in shape, member **2** being bounded by flared edges **6** and **6***a* and an aperture edge **8**. Similarly, member **2***a* is bounded by flaring edges **7** and **7***a* and an aperture edge **8***a*. Edges **8** and **8***a* may be straight or arcuate as shown at **18** and **18***a* of FIGS. **2** and **3**. Each triangular member **2** and **2***a* is slightly truncated at its apex, the truncation being so constructed and arranged that conductor **4** is smoothly joined without overlap at junction **9** to antenna member **2**. Likewise, conductor **4***a* is smoothly joined without overlap at junction **9***a* to antenna member **2***a*. It is to be understood that the respective junctions **9** and **9***a* are formed using conventionally available techniques for minimizing any impedance discontinuity corresponding to the junctions **9** and **9***a*.

It is also to be understood that the flared members **2** and **2a** of antenna **3** are constructed of material highly conductive to high frequency currents. It is further to be understood that the interior volume of antenna **3** may be filled with an air-foamed dielectric material exhibiting low loss in the presence of high frequency fields. Transmission line **1** may be similarly filled with dielectric material, such material acting to support conductor **4** in fixed relation to conductor **4a** and, likewise, the flared member **2** relative to member **2a**. Alternatively, the conductive elements of transmission line **1** and antenna **3** may be fixed in spaced relation by dielectric spacers such as represented by spacers **10** and **10a** seen located adjacent the aperture edges **8** and **8a** of antenna **3**.

The form of the transmission line **1** and the antenna **3** as illustrated in FIG. **1** is preferred, in part, because TEM mode propagation therein is readily established. The TEM propagation mode is preferred, since it is the substantially non-dispersive propagation mode and its use therefore minimizes distortion of the propagating signal. The simple, balanced transmission line structure permits construction of the invention with minimum impedance discontinuities.

Furthermore, it is a property of the symmetric type of transmission line **1** that its characteristic impedance is a function of b/h as defined in FIGS. **1** and **2**, where it is seen that b is the width dimension of the conductor major surfaces and h is the distance between the inner faces of the conductors. For example, the ratio b/h is kept constant in the instance of transmission line **1** because both b and h are constant.

According to the invention, the antenna **3** is made compatible with transmission line **1** by using the same value of the ratio b/h for both elements. In other words, if b/h is kept constant along the direction of propagation in antenna **3**, the characteristic impedance of antenna **3** will be constant along its length L and may readily be made equal to that of line **1**. By maintaining a continuously constant characteristic impedance along the structure including line **1** and antenna **3**, frequency sensitive reflections are prevented therein. It has been elected, for the sake of simplicity of explanation, to show in FIGS. **1**, **2**, and **3** triangular flaring and planar configurations for elements **2** and **2a**. It should be evident, however, that other configurations may readily be realized which maintain a constant characteristic impedance according to the above rule, and that such configurations may also be used within the scope of the present invention. The length L of the flared members **2** and **2a** must be large relative to the width of the antenna driving pulse (or to the rise time of a stepped driving excitation) or the antenna may lose directivity in azimuth angle Φ.

As previously noted, a system for exciting the inventive antenna of FIGS. **1**, **2**, and **3** should have compatible properties, such as being balanced in nature and avoiding the complicating deficiencies of an interface balun or other similar transition element. The system of FIG. **4** achieves such objectives and, in addition, makes beneficial use of the balanced dual element configuration of antenna **3** as part of the charging line for the excitation generator. It will be understood that certain liberties have been taken in the drawing of FIG. **4** better to explain the structure and operation of the device disclosed therein. For example, it is seen that FIG. **4** is intended schematically to indicate antenna conductor elements **2** and **2a** of FIG. **1** as respective single wire transmission lines **12** and **12a** having the same effective electrical characteristics as elements **2** and **2a** of FIG. **1** and the same radiating characteristics. As a further example, junctions **9** and **9a** in FIG. **1** are represented by junctions **19** and **19a** in FIG. **4**. The symbols **4** and **4a** in FIG. **1** are represented in FIG. **4** by symbols **14** and **14a** and identify the opposed conductors of transmission line **1**. Dimensions in FIG. **4** are grossly exaggerated, such as the spacing h between conductors **14** and **14a** of line **1**, as a matter of convenience.

At the left end of line **1**, conductors **14** and **14a** are joined by a series circuit comprising battery **21** coupled between resistors **20** and **20a** each having a resistance value of R/2 ohms. At the end of line **1** adjacent junctions **19** and **19a**, the conductors **14** and **14a** are joined by a series circuit comprising an electrically actuatable switch **23**; the blade terminal **27** of switch **23** is coupled by resistor **22a** to conductor **14a**, while the contact **26** of the switch is connected through resistor **22** to conductor **14**. Resistors **22** and **22a** each have a resistance value $r/2$ ohms, where r is equal to the characteristic impedance of line **1** (or antenna **3**) in ohms.

Square wave pulse generator **24** which produces the balanced square pulse wave form **24a**, is provided for actuation of switch **23**. Switch **23** may take the form of a single pole single throw mercury-wetted reed switch, several varieties of which are readily available on the market. Such reed switches may be closed and opened according to the presence or absence of a static magnetic field in the vicinity of the switch capsule. Thus, pulse generator **24** is adapted to open and close switch **23** by the agency represented by dotted line **25**, which may be a magnetic field excited by a solenoid (not shown) by pulse wave **24a**. It will be understood that square wave generator **24** may be replaced by a generator of pulse width modulated waves carrying an intelligence modulation such as voice or code modulation.

In operation, it will be observed that switch **23** is first separated from contact **26** by generator **24** for a time sufficient for the entire structure including the conductors of line **1** and antenna **3** to become charged to a potential difference V equal to that supplied by battery **21**. On the next cycle of wave **24a**, switch **23** closes with contact **26**, forming a conducting circuit path through resistors **22** and **22a**. The effect is that of putting a second source B in series with the effective source A of battery **21**, but reversed in polarity relative to the polarity of source A.

FIGS. **5a**, **6a**, **7a**, and **8a** show the positive voltage V, contributed by the source A or battery **21**, as a positive constant voltage at successive intervals in the system cycle. The same set of figures shows the progress of the negative wave due to the effective source B at the same successive intervals. For example, FIG. **5a** shows the situation at the instant switch **23** is closed; note that the wave due to the effective second source B has not started to flow.

In FIG. **6a**, however, the negative wave of voltage −V/2 from the effective second source B has begun to flow toward the aperture of antenna **3**. Upon reaching the ends of conductors **12** and **12a**, of FIG. **4**, and upon being reflected, the situation is depicted in FIG. **7a**. It is seen that when the −V/2 wave reaches the respective ends **8**, **8a** of antenna conductors **12** and **12a**, it is reflected and begins to flow back toward antenna junctions **19**, **19a**. The total contribution of the effective source B, beginning at the instant of reversal, is now −V volts. It will be seen that the total potential due to sources A and B between conductors **12** and **12a** at the aperture **8**, **8a** of the antenna **3** at the instant of reversal suddenly drops from +V volts to zero; this instant of time is one of primary interest in the operation of the invention. The wave due to the effective source B continues to travel back toward junctions **19**, **19a** until the antenna **3**, which has served as part of the charging line for the system, is substantially completely discharged, if the value of r is the characteristic impedance of line **1**. The charging cycle is then reestablished by the closure of switch **23** and the system may be repeatedly recycled.

It will be readily appreciated that the total potential difference seen across the aperture **8**, **8a** of antenna **3**, for the same successive instants of time as described above, may be illustrated as in the respective FIGS. **5b**, **6b**, **7b**, and **8b**. It is seen that the potential at the antenna aperture due to source A (battery **21**) is progressively eaten away by the travel of the wave due to the effective source B started toward the aperture **8**, **8a** when switch **23** is closed and then reflected at the aperture ultimately to effect substantial discharge of the line formed by conductors **12** and **12a**, the wave having returned to the source resistances **22**, **22***l*.

As noted previously, it is the instant of reflection of the wave from the effective source B at the distance L along conductors **12** and **12a**, (the aperture of antenna **3**) that is of prime interest. Because of the finite characteristic impedance r of the antenna 3, the leading edge of the −V/2 wave launched into the aperture or mouth of the antenna, which is in effect an open circuit, reverses in direction of flow while maintaining its previous polarity. Radiation into space of a signal proportional to dV/dt must occur at this instant of time. No further radiation can obtain until after switch 23 is recycled and conductors 12 and 12a are recharged.

As noted above, if the resistance r of the sum of resistors 22 and 22a is made equal to the characteristic impedance of the transmission line system, the reflected wave front terminates in resistors 22, 22a and the potential difference across the entire line drops to substantially zero and begins to recharge to approximately rv/R volts. If the value of r is reduced toward zero, the potential across aperture 8, 8a tends to increase, but the response of the system may be ringing or oscillation for an extended time. A moderate length of transmission line added between the series circuits 22, 22a, 23, and junctions 19 and 19a may then be used to delay the instant of time at which radiation occurs.

FIG. 9 illustrates a form of the invention employing many of the same elements as used in FIG. 4 and they are therefore identified with similar reference numerals, including transmission line conductors 14, 14a, antenna conductors 12, 12a, battery 21, terminals 19, 19a, mercury reed switch elements 23, 26, 27, source resistors 22, 22a, and means 25 for actuation of switch blade 23. A moderate length of transmission line has been added between the series circuit 22, 22a, 23 and the respective junction points 19, 19a. The added line comprises a first inner conductor 31 connecting resistor 22 to junction 19, and a second inner conductor 31a connecting resistor 22a to junction 19a, and an outer tubular conductor 30 surrounding and shielding conductors 31 and 31a. For the purpose of ensuring that shielding conductor 30 is at the mid-potential between conductors 31, 31a, fixed capacitors 33, 33a are placed in series across battery 21, being mutually coupled at a mid-terminal 36 which is also connected to mid-terminal 37 between adjustable trimming capacitors 34 and 34a also placed across battery 21. The mid-terminal 37 is coupled by balanced leads 38, 38a in a balanced manner to the shield conductor 30. With a 300-volt battery 21, a far field receiver used with the impulse transmitter of FIG. 9 receives a signal very closely approximately an impulse with a rise time and duration less than 200 picoseconds.

A preferred method of employing the invention is shown in FIG. 10 wherein a further advantageous arrangement for connecting the mercury reed switch is disclosed. In this apparatus, parts similar to those appearing in FIGS. 4 and 9 bear the same reference numerals. In FIG. 10, actuation means 25, which may be a magnetic field supplied by a solenoid (not shown) excited by a pulse generator similar to pulse generator 24 of FIG. 4 or by a pulse width modulated generator, is adapted to move switch blade 123 cyclically between terminals 126 and 127. Blade 123 is coupled through r/2 resistor 122b to conductor 14. Terminal 127 of the switch is coupled through r/2 resistor 122 to conductor 14a. Likewise, terminal 126 is coupled through r/2 resistor 122a to conductor 14a.

Referring to FIGS. 10 to 13, switch blade 123 spends the major part of its operating time in contact either with switch terminal 126 or switch terminal 127 as shown especially in FIG. 11; blade 123 is at terminal 126 in the time interval a–b and is at terminal 127 in time interval c–d, for example. During transit from terminal 126 to terminal 127 (in the period b–c which is about 100 microseconds in representative-reed switches), the conductors 12 and 12a of the antenna recharge from battery 21 through resistors 20 and 20a. When the blade 123 touches switch contact 126 or switch contact 127, the potential between conductors 14, 14a, drops virtually to zero. As in FIG. 12, the line conductors 14, 14a, and antenna conductors 12, 12a charge in the interval ending at a, when discharge is brought about substantially instantaneously in a time on the order of 100 picoseconds. The cycle represented in FIGS. 11 and 12 repeats at each switch closure at terminal 126 or 127. As in the apparatus of FIG. 4, the far field signal of the antenna is a function of the time derivative of the collapsing voltage at time a, being seen by the receiver primarily as a series of sharp impulses of brief duration, as in FIG. 13. The sharp pulse series is scarcely modified because of the slowly varying voltage change during the period b–c, for example. From the foregoing, it is evident that the possibility of a higher repetition rate is characteristic of the apparatus of FIG. 10. Also, operation at reduced average potentials on conductors 14, 14a is possible.

It will be apparent to those skilled in the art that the mercury-wetted reed switch, because of its compactness and other advantageous properties, is a practical externally controlled switch for employment in the invention. Other types of switches may also readily be employed in the apparatus of FIGS. 4, 9, and 10, such as semiconductor switches of well known types whose state of conductivity may be controlled by external pulse generators, such as generator 24 of FIG. 4.

Other semiconductor switching arrangements may be employed, including the inventive system shown in FIG. 14; in this figure, elements common to those in FIG. 4 are identified by the same reference numerals, including the balanced r/2 resistors 22 and 22a in series connection across conductors 14, 14a, of transmission line 1. Between resistors 22 and 22a, are placed series connected transistors 50 and 50a, the total series circuit including resistor 22, the collector and emitter of transistor 50, the collector and emitter of transistor 50a, and resistor 22a. Between the base and emitter of transistor 50 is connected a resistor 51; between the base and emitter of transistor 50a is similarly connected a resistor 51a. Resistors 22 and 22a are in balanced configuration and are selected so that when the transistors are conducting, the total resistance in series with transistors 50, 50a is equal to r, the characteristic impedance of line 1 and antenna 3. Resistors 51, 51a serve to provide a direct current path between the respective bases and emitters of transistors 50, 50a; their resistance values must be great enough to permit avalanche operation of transistors 50, 50a.

In operation, the circuit of FIG. 14 with the transistors 50, 50a non-conducting permits battery 21 to charge line 1 and antenna 3, so that the effective capacitance 52 of the system approaches full charge. Transistors 50, 50a are avalanche mode devices which break down into avalanche conduction when the voltage between terminals 19, 19a reaches an appropriate value. In practice, one or more such transistors may be employed, depending upon the desired charging level for line 1 and antenna 3. The abrupt discharge of current through transistors 50, 50a starts a voltage wave propagating along conductors 12, 12a toward the aperture 8, 8a of the antenna 3. Upon reversal of the voltage wave at the aperture 8, 8a, a differentiated impulse is radiated toward the far field of antenna 3. The voltage wave reflected at the instant of reversal ultimately drops the potential difference between terminals 19, 19a to the point of extinction of current flow through transistors 50, 50a. The circuit is then in condition for recharging from battery 21 and automatically continues to recycle unless the voltage from battery 21 is removed.

In the foregoing, several embodiments of the invention have been described by means of which impulse radiations may be projected directionally into space. It is seen that the disclosed embodiments beneficially employ constant impedance transmission line systems supporting the non-dispersive TEM mode of energy propagation. It is furthermore seen that the total transmission line is employed cyclically for the cooperative storage of electrical energy and for its controlled release for propagation along the transmission line toward an open circuited end of the transmission line. Upon reflection of the electrical energy at the open circuit, directive radiation of an impulse nature occurs instantaneously. In the invention, cooperative use is made of parts formerly playing only the function of an impulse generator part, or only the function of an antenna part. An integrated, compact apparatus is thus provided for the generation and radiation of impulse waves. It will be clear to those skilled in the art that the natural storage capacitance of the transmission line system may be augmented or that other electrical storage means may be employed. Furthermore, it will be apparent that other transmission lines propagating the non-dispersive TEM mode may be employed according to the invention. It is also clear that no discrete physical transition such as junctions **19**, **19***a* need appear in the structure, and that the transmission line system may employ a continuous system without a recognizable discontinuity between the functional sections of the line.

While the invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. Apparatus for radiating impulses of electromagnetic energy comprising:

balanced conductor high frequency transmission line means having a substantially constant characteristic impedance between first and second ends thereof,

current source means adjacent said first end having a first time constant for uniformly charging said transmission line means, and

switching circuit means having conducting and non-conducting states adjacent said first end and having when in said conducting state a second time constant substantially shorter than said first time constant for causing a field collapsing wave to propagate on said transmission line means to said second end thereof for partially discharging said transmission line means,

said second end of said transmission line means being adapted to reflect said field collapsing wave to propagate on said transmission line means toward said first end for substantially totally discharging said transmission line means into said switching circuit means,

said second end of said transmission line means being further adapted to serve as an antenna aperture for radiating an impulse of electromagnetic energy into space at the instant of reversal of propagation of said field collapsing wave.

2. Apparatus as described in claim **1** wherein the impedance of said switching circuit means is substantially equal to the characteristic impedance of said transmission line means.

3. Apparatus as described in claim **1** wherein said balanced conductor transmission line means has first and second planar conductors with opposed major conducting surfaces.

4. Apparatus as described in claim **3** wherein said major conducting surfaces have a width b and a separation h where the ratio *b*/*h* is held substantially constant.

5. Apparatus as described in claim **3** wherein said planar conductors are adapted to propagate traveling electromagnetic waves in the transverse electromagnetic mode.

6. Apparatus as described in claim **4** wherein said planar conducting surfaces have a region adjacent said second end in which *b* progressively expands for the purpose of forming said electromagnetic radiating antenna aperture.

7. Apparatus as described in claim **3** wherein said first planar conductor has substantially the shape of a truncated equilateral triangle, the base of which forms the said second end of said first planar conductor.

8. Apparatus as described in claim **5**, wherein said current source means for charging said line comprises:

unidirectional potential means, and

first and second resistance means of substantially equal resistance,

said potential means being connected through said resistance means to said transmission line means.

9. Apparatus as described in claim **5**, wherein said switching circuit means for discharging said line comprises:

switch means,

first and second resistance means of substantially equal resistance,

said switching means being connected through said resistance means to said transmission line means.

10. Apparatus as described in claim **9**, wherein said substantially equal resistors have a total resistance substantially equal to the characteristic impedance of said transmission line means.

11. Apparatus as described in claim **1** wherein said switching circuit means comprises first and second substantially equal impedance means and switch means, said switch means being connected in series relation between said first and second impedance means, the total impedance of said switching circuit means being substantially equal to the characteristic impedance of said transmission line means.

12. Apparatus as described in claim **1**, wherein said switching circuit means for discharging said transmission line comprises switch means adapted to be switched by a pulsed electrical signal.

13. Apparatus as described in claim **1**, wherein said switching circuit means for discharging said transmission line comprises semiconductor switch means adapted to initiate discharge when the potential across said transmission line means reaches a predetermined value.

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