RADIATION MODULATING SYSTEM

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Claims. (Cl. 250—17)

This invention relates to systems and methods of communication and more particularly to the generation, transmission and reception of radio waves. This application is a continuation-in-part of our copending application Serial No. 39,286, filed July 17, 1948, now matured into U. S. Patent 2,539,594, and Serial No. 126,494, filed November 10, 1949.

An object of the invention is to provide a new and improved system for the modulation of radio waves. A further object is to provide a novel system for modulating radio waves in accordance with signals received by radiation detectors such as alpha, beta and gamma ray counters. Other and further objects will be explained hereinafter and will be particularly pointed out in the appended claims.

The invention will now be more fully explained in connection with the accompanying drawings in which Fig. 1 is a diagrammatic view of circuits and apparatus constructed in accordance with the present invention and illustrating the transmission of radio waves modulated according to the principles of the present invention; Fig. 2 is a similar diagram illustrating the modulating of a multi-channel system; Fig. 3 is an experimental curve illustrating the operation of portions of the systems of Figs. 1 and 2 for various added antenna lengths; Fig. 4 is a reproduction of experimentally-obtained curves illustrating the performance of portions of the systems of Figs. 1 and 2; Fig. 5 is a schematic diagram illustrating a particular gaseous radiation-counter-tube modulation system and Fig. 6 is a similar diagram of a solid radiation counter modulation system.

An antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy supplied to the antenna by a radio-frequency-energy-generating electric system to which the antenna may be electrically connected is shown in Fig. 1.

For purposes of illustration, the antenna is shown as comprising two dipole segments 2 and 4, though any other antenna may similarly be employed. A radio-frequency oscillator 6 constitutes such an electric system or source of radio-frequency energy connected to the antenna, for example, by a transmission line 1 in order electrically to excite the antenna to emit radio waves into space. A two-electrode gas-discharge tube 44 is shown connected with one electrode 48, shown as a wire electrode, in contact with the antenna element 4, and with the other electrode 50, shown disposed substantially in line with the electrode 48, in contact with an adjacent antenna element 8. Upon ionization of the gas in the tube 44, the elements 4 and 8 become tightly coupled as a result of the low impedance of the conducting tube 44, the elements 4 and 8 being loosely coupled as a result of the high impedance of the non-conducting tube 44. Strong modulation effects are produced, as described in the said copending applications, due to the connecting and disconnecting processes controlled by this ionic switching means of variable impedance.

The depth of amplitude modulation produced during the sixty-cycle ionization and de-ionization switching by a two-watt neon tube 44 of antenna sections 8 having different lengths ΔL to and from the antenna element 4, operating at about 140 megacycles radio frequency, is shown in Fig. 3. As explained in the said copending applications, regions L3 have been found where increased antenna length ΔL increases the depth of modulation; regions L4 have also been found where an increased antenna length ΔL decreases the depth of modulation; and regions L1 where the antenna length may be increased with substantially constant modulation effects have also been detected.

As also explained in the said copending applications, if tightly coupled generating systems are employed, frequency and phase-modulation may be produced. A crystal-controlled system 6, on the other hand, produces substantially pure amplitude modulation. Amplitude-modulation side bands of several megacycles width have been easily obtained with a carrier frequency of about 125 megacycles. As an illustration of the degree of frequency modulation produced by a tightly coupled system having a half-wave dipole operating with radio waves of about 140 megacycles frequency and employing a 2-watt neon tube 44 between the two antenna segments 4 and 8, a total frequency modulation of about 50 kilocycles was obtained for a 400-cycle, 25-volt alternating current ionizing and de-ionizing signal. A 25-volt, 1000-cycle modulating signal produced a 10 kilocycle spread, and a 40-volt signal of the same frequency produced a 38 kilocycle spread.

The amount of modulation may be varied not only by varying the amount of added antenna length 8, but also by varying the degree of ionization of the gas tube, and by other means. A typical experimentally-obtained variation of amplitude modulation with variation of ionization signal-strength, or of the degree of ionization of the neon tube, is plotted in curve C of Fig. 4.

We have found that the slope and general shape of the modulation curves may be altered by varying the length of the antenna elements, by the gas concentrations and pressure in the tube, by the bias voltage, and by other adjustments. Approximately linear, square-law, parabolic, cubic, exponential and other shapes have been produced. As an illustration, a sixty-cycle operated two-watt neon tube connected symmetrically between two parasitic elements, excited by 140-megacycle waves, produced a substantially exponential modulation curve for an element length of about eighty-three inches; a substantially square-law curve for an element length of about thirty inches; and a long, substantially linear curve-port for an element length of about forty inches.

As discussed in the said copending applications, the antenna elements 4 and 8 may also be used as the parasitic type, supporting received radio energy and re-transmitting the same, or they may be connected to a receiver electric system, not shown. Curve D of Fig. 4, for example, plots an experimentally-determined variation of amplitude of modulation during the sixty-cycle ionization and de-ionization of the tube 44 in a parasitic reflector antenna system 4-8.

The circuit of Fig. 1 has particular application for the remote counting and observing of various types of radiation signals such as cosmic rays, alpha, beta or gamma rays, radio-active particles, charged particles, and the like. Such radiation will periodically ionize the tube 44, as it is passed through the walls of the tube that are, for example, made of glass to permit the radiation to effect the ionization. The tube, of course, may be initially biased, as is done by a direct-current source 52, schematically shown connected thereacross in a circuit of appropriate impedance, to sensitize and condition it so that weak radiations may produce their effects. As the tube is ionized or further ionized, modulation results in the transmitted radio waves. A receiver at a remote point, therefore, will receive the transient modulations produced as the tube 44 is ionized and de-ionized by the radiation. If the receiver is connected to a tape recorder, for example, the number or frequency...
of bursts in the tube 44 may be recorded. The amplitude of the transient modulation effects, furthermore, as shown in Fig. 4, is a measure of the degree of ionization and hence of the number or intensity of particles or rays causing the ionization. Alternately, the same information may be obtained from the frequency or phase spread of the resulting frequency or phase modulation if a tightly coupled system 6 is utilized.

Not only may the tube 44 be operated over a substantial linear portion of the modulation curves C and D, Fig. 4, to produce modulation changes in proportion to the modulating signal voltage or to the degree of ionization of the gas, but operation may also be effected on the plate-like portion as more clearly shown in curve D, to produce a constant amplitude of modulation irrespective of the intensity of the modulating signal. This condition may be of value where only frequency modulation is desired or where it is desired to count cosmic-ray and other radiation bursts with a constant impulse amplitude modulation irrespective of the intensity of the radiation bursts.

An automatic, remote radiation counter and analyzer is thus provided which has particular use where vacuum tubes and other conventional vacuum devices cannot be used. If the system 4—8 is parasitic, as shown, for example, in Fig. 5, it may be employed in a region of atomic fission or on a rocket or projectile in space. Radio waves may be reflected in the system 4—8 by a remote transmitter-receiver which may be a radar system. Other uses and applications for these instruments will, of course, immediately suggest themselves to those skilled in the art.

The gas tube 44 may be of the Geiger-Mueller radiation counter type, particularly where extremely high repetition rates of bursts are to be measured. One of the more conventional such counter tubes is shown at 76 in Fig. 5. The tube 76 may be provided with a concentric cylindrical anode and cathode 70 and 78, a biasing voltage source 52, an impedance shown as a limiting resistor 80, which can also be used in connection with the other embodiments of the invention, as shown in Fig. 6, and a conventional external quenching circuit 82 such as an R-C. circuit. The tube 76, furthermore, may be filled with a self-quenching polyatomic gas, as is well known in the art.

Returning to Fig. 1, the elements 2—4 are shown as constituting a driving antenna, but they may, of course, be used as a receiving antenna or as parasitic elements. The element 4 is connected to one electrode 48 of the gas-discharge tube 44, which may be a Geiger-Mueller tube, and the other electrode of the tube 44 is connected to one end of the additional antenna section 8, as before described. The additional element 8, however, is connected at its other end to one electrode 48' of a second discharge tube 44', and the other electrode 50' of the second discharge tube 44' is connected to one end of another antenna section 8'. The other end of the section 8' is similarly connected to one electrode 48'' of a further tube 44'', the other electrode 50'' of which connects to a further antenna element 8'', and so on.

If the tubes 44, 44' and 44'' may be so constructed that the tube 44 will ionize upon the reception of less radiation from charged particles and the like than the tubes 44' and 44'', and the tube 44'' will, in turn, conduct, with less radiation than the tube 44'. This result may be obtained, for example, by using successively lower gas pressures in the successive tubes. The tubes, furthermore, may be provided with different biasing voltages schematically illustrated at 52, 52' and 52'' to attain the same result. A weak radiation-burst signal may thus ionize the tube 44, but not the tubes 44' and 44'', so that a modulation will be produced corresponding to the transient addition and removal of the antenna section 8. Other bursts increase in intensity as the depth of modulation increases as shown in Fig. 4. With more intense radiation beyond the said first range, the tube 44' will also be ionized, giving an instantaneous response corresponding to the addition and removal of both sections 8 and 8'. If the system is operating on, for example, the slope of the portion L5 of the characteristic curve 5 as shown in Fig. 3, a marked further increase in reference level of modulation will be effected the moment the additional section 8' is added. For further increases in radiation over a second range, therefore, an increase in amplitude of modulation will occur as plotted in Fig. 4. When very intense radiation is present, the tube 44'' will then also be ionized, adding the additional antenna section 8'' and producing an even greater amplitude of reference modulation level over a third range.

By employing a plurality of tubes, therefore, which may, of course, be more or less than the number three illustrated in Fig. 1, a multiple-scale radiation counter is provided in a single instrument having as many multiple counting scales as may be desired for measuring the intensity of the radiation bursts as it counts the number of bursts.

In a similar manner, the circuit of Fig. 1 may be employed to count the radiation burst-rate on separate scales corresponding, for example, to ten, hundreds, thousands, etc., of bursts per second. If each of the successive tubes 44', 44'', 44''' etc. is provided with a successively higher counting limit beyond which it cannot count, as may be effected by the use of different quenching circuits 82', as shown in Fig. 5, or different gases or gas conditions, as is well known in the art, all three tubes will count up to a certain number of bursts, say units of tens, which will be directed as modulation impulses to a reference modulation level. When the rate of the bursts exceeds this number, only tubes 44 and 44'' will then be periodically ionized and will count up to a higher number of bursts, say hundreds, at a reference modulation level. When the burst-repetition-rate exceeds this higher number, tube 44 alone will then be periodically ionized and will count up to still a higher number of bursts, say thousands, at still a different reference modulation level, and so on.

Thus an automatic multiple counter of the frequency of the bursts is provided in one instrument having as many multiple counting scales as may be desired for measuring the number of bursts per unit time.

If it is desired that constant-modulation impulses be produced irrespective of the intensities of the radiation bursts, as previously mentioned, the tubes may be operated on the plate-like portion of the characteristic curve shown in curve D of Fig. 4.

It is further to be understood, when operating the tube, such as 44, along the linear portion of the characteristic curve, for example, it is possible to change the amplitude modulation which increases with increasing ionization. The radiation intensity or rate of ionization may be employed to count multiple scales of the radiation intensity or rate effects. Alternately, the oscillators 6 and 6' may operate at the same radio frequency but may be modulated by different-frequency signals to identify them. The instantaneous modulation upon these identifying signals produced by the bursts in the respective gas tubes will then be associated with the respective transmitters 6 and 6'.

While the preceding discussion has been limited to an increase or decrease in depth of amplitude modulation with varying degrees of ionization of the gas tubes, it is to be understood that this technique may be employed with the various degrees of frequency or phase modulation which may be produced, as previously discussed. Instead of using the depth of amplitude modulation, therefore, as the measure of the number of bursts, radiation may be obtained, as is well known in the panoramic art, from the frequency side bands of the frequency or phase modulation that is produced.

As a further example, a solid radiation counter 66,
such as a diamond crystal, is illustrated in Fig. 6, dis-
posed between two antenna elements or other high-fre-
quency conductors 4 and 8. The diamond 66 is placed
in a strong electric field supplied, for example, by a
source of energy as with a limiting resistor
R. It has been found that when alpha, beta or gamma
rays or other similar charged particles are impinged
upon the diamond, they become instantaneously ab-
sorbed in the diamond 66, inserting a sharp, instan-
taneous pulse or flow of electrons across the diamond.
This effect is often referred to as an instantaneous
"ionization" of the diamond crystal, and this instan-
taneous absorption of the radiations by the antenna ele-
ments 4 and 8 is the initial stage. At the instant that the electrical char acteristics of the diamond are so suddenly and instantaneously affected, thereby to produce a corresponding pulse modulation of the radio waves emitted by the antenna elements.

The antenna elements 4 and 8 may be either driven or parasitic elements and may be conveniently disposed on a rocket or other projectile to act as a remote radiation counter, as before described. The symmetrical disposition of the counter 66 and the equal lengths of the elements 4 and 8 are not, of course, necessary, though preferable in some instances. The counters of other embodiments of the invention may similarly be

While the foregoing description has been limited to driving parasitic or antenna elements, it is to be under-
stood, as implied by the classification, that the
same phenomena occur when the tubes or other con-
counters connect any other conductors carrying radio-
frequency energy, such as transmission lines or portions of tank circuits, or other radio-frequency conducting sections.

Further modifications will occur to persons skilled in
the art and all such are considered as falling within the spirit and scope of the invention as defined in the ap-

What is claimed is:

1. A radio transmitter for remote radiation measure-
ments having, in combination, an antenna of the type
that emits radio waves into space in response to elec-
trical excitation by radio-frequency energy drawn from
a radio-frequency-energy generating electric system prior
to the emission of the radio-frequency as radio waves,
an electric system for generating radio-frequency energy,
means electrically connecting the antenna to the electric
system in order that the antenna may draw radio-
frequency energy from the electric system, thereby to
cause the antenna to emit radio waves into space, radio-

counter means provided with electrodes, means for con-
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ting one of the electrodes to a section of an antenna,
and means for enabling the counter means to receive radiations and to
produce an electrical impulse between the electrodes in
response thereto in order to add or remove the section of
antenna to or from the antenna to vary a dimension of
the antenna during the emission of the radio waves by
the antenna, thereby to emit radio waves emitted by the antenna in accordance with the radiations detected by the radiation counter means.

2. A radio transmitter for remote radiation measure-
ments having, in combination, an antenna of the type
that emits radio waves into space in response to elec-
trical excitation by radio-frequency energy drawn from
a radio-frequency-energy generating electric system prior
to the emission of the radio-frequency as radio waves,
an electric system for generating radio-frequency energy,
means electrically connecting the antenna to the electric
system in order that the antenna may draw radio-
frequency energy from the electric system, thereby to
cause the antenna to emit radio waves into space, gaseous-
discharge radiation counter means provided with elec-
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trodes and means for connecting one of the
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6. A radio system having, in combination, an antenna
having first and second sections for transmitting or re-
ceiving radio waves, an ionizable radiation counter hav-
ing a pair of electrodes, means for connecting one elec-
drode to the first section of the antenna and the other
electrode to the second section of the antenna, means
for conditioning the radiation counter to produce an
ionizable discharge between the electrodes, and means
responsive to radiations received by the counter for
modifying the ionization of the counter in accordance
with the radiations, the counter thereby to control the
radio waves transmitted or received by the antenna.

7. A radio system having, in combination, antenna
means comprising a plurality of successive antenna sec-
tions for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a plurality of successive antenna sections, for transmitting antenna means comprising a 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different modulations of the radio waves transmitted or received thereof in response to the different signals.

8. A radio system having, in combination, antenna means comprising a plurality of successive antenna sections for transmitting or receiving radio waves, a plurality of radiation-counter elements each element of which is provided with electrodes and is responsive to ionizing signals, each radiation-counter element corresponding to a pair of adjacent antenna sections of the plurality of successive antenna sections, and means for connecting the electrodes of each of the radiation-counter elements corresponding to the corresponding adjacent antenna sections so as instantaneously to change a dimension of the antenna means by varying amounts depending upon which of the radiation-counter elements is ionized, thereby to effect different modulations of the radio waves transmitted or received thereof in response to the different signals.

9. A radio system having, in combination, antenna means comprising a plurality of successive antenna sections for transmitting or receiving radio waves, a plurality of successively disposed gas-discharge elements each element of which is provided with electrodes and is responsive to ionizing signals of successively increasing intensity, each gas-discharge element corresponding to a pair of adjacent antenna sections of the plurality of successive antenna sections, means for connecting the electrodes of each of the gas-discharge elements in succession to the corresponding adjacent antenna sections so as instantaneously to change a dimension of the antenna means by successively increasing amounts as successive gas-discharge elements are ionized, thereby effecting successively increasing modulations of the radiated radio waves in response to the ionizing signals in order to measure the frequency and the intensity of the signals.

10. A radio system having, in combination, antenna means comprising a plurality of successive antenna sections for transmitting or receiving radio waves, a plurality of successively disposed radiation-counter elements each element of which is provided with electrodes and is responsive to ionizing signals of successively increasing intensity, each radiation-counter element corresponding to a pair of adjacent antenna sections of the plurality of successive antenna sections, means for connecting the electrodes of each of the radiation-counter elements in succession to the corresponding adjacent antenna sections so as instantaneously to change a dimension of the antenna means by successively increasing amounts as successive radiation-counter elements are ionized, thereby effecting successively increasing modulations of the radiated radio waves in response to the ionizing signals in order to measure the frequency and the intensity of the signals.

11. A radio system having, in combination, plurality of first and second radio-frequency conducting sections for transmitting or receiving radio waves, a plurality of ionizable radiation counters corresponding to the plurality of conducting sections and each having a pair of electrodes, means for connecting one electrode of each counter to the first section and the other electrode to the second section of the corresponding sections, means for conditioning the counters to produce an ionization discharge between the electrodes, and means responsive to radiations received by the counters for modifying the ionization of the counters in accordance with the radiations, thereby to signal-modulate the radio-frequency energy transmitted or received by the sections.

12. A radio system having, in combination, a plurality of antennas having first and second sections for transmitting or receiving radio waves along a plurality of channels, a plurality of ionizable radiation counters corresponding to the plurality of antennas and each having a pair of electrodes, means for connecting one electrode of each counter to the first section of the corresponding antenna and the other electrode to the second section of the corresponding antenna, means for conditioning the counters to produce an ionization discharge between the electrodes, and means responsive to radiations received by the counters for modifying the ionization of the counters in accordance with the radiations, thereby to signal-modulate the radio waves transmitted or received by the antennas along the plurality of channels.

13. A radio system having, in combination, an antenna element of the type that transmits and receives radio waves, a radiation-counter circuit responsive to charged-particle radiations, and means for connecting the radiation-counter circuit to the antenna element so as instantaneously to add the counter circuit to the antenna element and thus to change a dimension of the element in accordance with the particle radiations received by the counter circuit during the transmission or reception of the radio waves by the element, thereby to effect modulation of the transmitted or received radio waves in response to the particle radiations.

14. A radio system as claimed in claim 11 and in which the radiation counters connected to the corresponding conducting sections are each provided with means for adapting each counter to count different rates of occurrence of radiation bursts.

15. A radio system as claimed in claim 14 and in which the adapting means are adjusted to relate the said different rates by a factor or factors of ten.

16. A radio system as claimed in claim 11 and in which the radiation counters connected to the corresponding conducting sections are each provided with means for adapting each counter to respond to radiation bursts of different intensities.

17. A radio system as claimed in claim 11 and in which the radiation counters connected to the corresponding conducting sections are each provided with means for adapting each counter to respond to radiation bursts of different characteristics.

18. A radio system as claimed in claim 12 and in which means is provided for tuning each of the plurality of channels to a different radio-frequency.

19. A radio system as claimed in claim 18 and in which each of the radiation counters is provided with means for adapting each counter to respond to radiation bursts of different characteristics.

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