March 1, 1955 R. H. RINES ET AL 2,703,363

RADIATION MODULATING SYSTEM

Filed Jan. 23, 1951

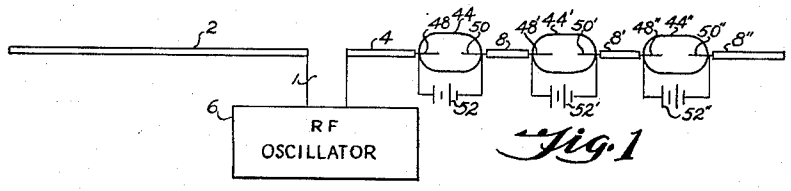

Fig. 1

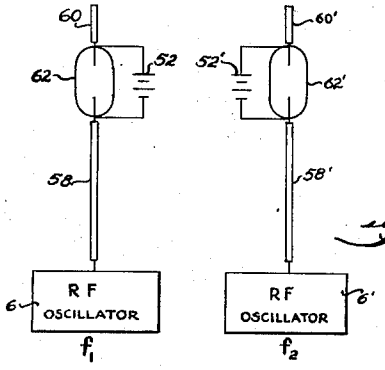

Fig. 2

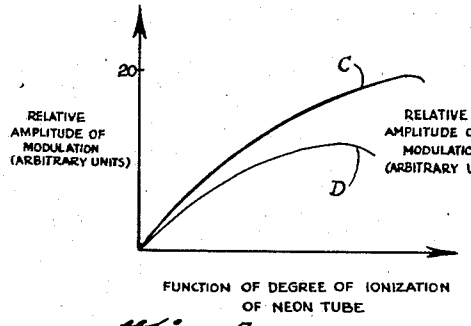

Fig. 4

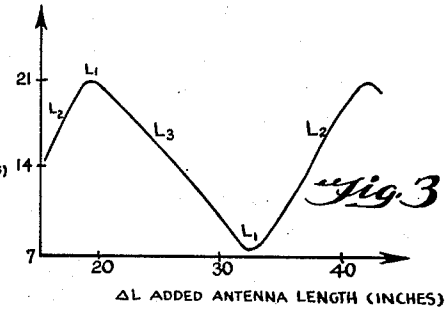

Fig. 3

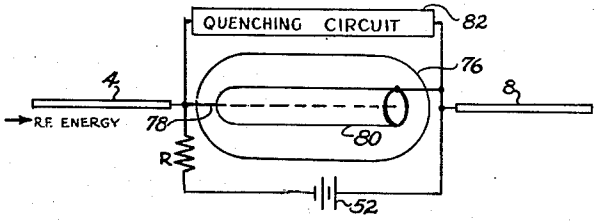

Fig. 5

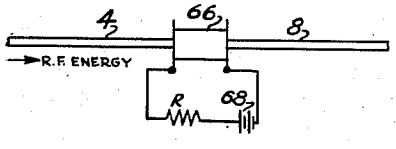

Fig. 6

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United States Patent Office 2,703,363
Patented Mar. 1, 1955

2,703,363

RADIATION MODULATING SYSTEM

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Application January 23, 1951, Serial No. 207,295

19 Claims. (Cl. 250—17)

The present 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 applications, 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 or section **8**. Upon ionization of the gas in the tube **44**, the antenna sections **4** and **8** become tightly coupled as a result of the low impedance of the conducting tube **44**, thereby effecting a low impedance electrical connection between the antenna elements **4** and **8**; and upon deionization of the gas in the tube **44**, the elements **4** and **8** are 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, during the connecting and disconnecting processes controlled by this ionic switching means of variable impedance.

The effect on 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, reigons L_2 have been found where increased antenna length ΔL increases the depth of modulation; regions L_3 have also been found where an increase in antenna length ΔL decreases the depth of modulation; and regions L_1 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 **6** 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 38 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 of modulation with variation of modulation 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 controlled by the length of the antenna elements, by the gas concentration 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 over-all 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-portion for an element length of about forty inches.

As discussed in the said copending applications, the tube **44** may, if desired, have further electrodes such as, for example, band electrodes outside the tube, magnetic-field deflection coils or any other well-known multiple electrode arrangements. A multiplicity of tubes may be employed on either or both of the antenna segments for purposes that will subsequently be explained. As further disclosed in the said copending applications, the antenna elements **4** and **8** may also be of 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 deionization 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, of glass to permit the radiations to effect the ionization. The tube, of course, may be initially biased, as 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, a 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 deionized 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 substantially 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 tube, but operation may also be effected on the plateau-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 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 instruments can not 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 from 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 of such counter tubes is shown at 76 in Fig. 5. The tube 76 may be provided with a concentric cylindrical anode and cathode 80 and 78, a biasing voltage source 52, an impedance shown as a limiting resistor R, which may 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 driven 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 50 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 a further 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 still a further antenna element 8″, and so on.

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. Over a first range, as the bursts increase in intensity, 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 antenna dimension change 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 L_2 of the characteristic curve plotted in Fig. 3, a marked 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 tens, 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 having a certain 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 different reference level of modulation. 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-burst signals, as previously mentioned, the tubes may be operated on the plateau-like portion of the characteristic curve shown in curve D of Fig. 4.

It is further to be understood that, by operating the tube, such as 44, along the linear portion of the characteristic, Fig. 4, a plurality of independent signals may be transmitted without interaction, whereas, operation on the non-linear portions of curves C and D will effect any desired resultant effect.

It may be preferable, furthermore, to employ different radio-frequency channels with the differently-sensitized gas tubes to count the corresponding units of radiation intensities or burst rates. To the attainment of this end, an oscillator 6 may energize an antenna 58 to transmit radio waves of frequency f_1, as shown in Fig. 2. When the gas tube 62 which may, for example, be heavily biased by the source schematically illustrated at 52, is ionized by radiation effects up to a given intensity or up to a given rate, the segment 60 will be instantaneously added to and removed from the segment 58, producing modulation which increases with increasing ionization. When a radiation intensity or rate in excess of the said given intensity or rate is reached, a less heavily biased tube 62′ connected to a smaller voltage source 52′, and connected also to antenna element 58′, will be periodically ionized to transmit modulation on a different frequency channel f_2. Different frequency channels may thus 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-frequencied 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 increased or decreased spreads of frequency or phase modulation may also be produced, as previously discussed. Instead of using the depth of amplitude modulation, therefore, as the measure of the degree of ionization or other effect, the same information 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 disposed between two antenna elements or other high-frequency conductors 4 and 8. The diamond 66 is placed in a strong electric field supplied, for example, by a source 68 connected in series 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 absorbed by the diamond 66, initiating a sharp, instantaneous pulse or flow of electrons across the diamond. This effect is often referred to as an instantaneous "ionization" of the diamond crystal, and this instantaneous phenomenon connects the antenna elements 4 and 8 at the instant that the electrical characteristics of the diamond are so suddenly and instantaneously affected, thereby to produce a corresponding pulse modulation of the radio-wave carrier transmitted or received 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 the other embodiments of the invention may similarly be of the solid type.

While the foregoing description has been limited to driven, receiving or parasitic antennas, it is to be understood, as explained in the copending applications, that the same phenomena occur when the tubes or other 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 to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A radio transmitter for remote radiation measurements having, in combination, an antenna of the type that emits radio waves into space in response to electrical 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, radiation counter means provided with electrodes, means for connecting one of the electrodes to the antenna and another electrode to a section of antenna, and means for enabling the radiation 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 effect modulation of the radio waves emitted by the antenna in accordance with the radiations detected by the radiation counter means.

2. A radio transmitter for remote radiation measurements having, in combination, an antenna of the type that emits radio waves into space in response to electrical 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 electrodes, means for connecting one of the electrodes to the antenna and another electrode to a section of 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 and from the antenna to vary a dimension of the antenna during the emission of the radio waves by the antenna, thereby to effect modulation of the radio waves emitted by the antenna in accordance with the radiations detected by the radiation counter means.

3. A radio transmitter for remote radiation measurements having, in combination, an antenna of the type that emits radio waves into space in response to electrical 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, Geiger counter means provided with electrodes, means for connecting one of the electrodes to the antenna and another electrode to a section of 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 and from the antenna to vary a dimension of the antenna during the emission of the radio waves by the antenna, thereby to effect modulation of the radio waves in accordance with the radiations detected by the counter means.

4. A radio transmitter for remote radiation measurements having, in combination, an antenna of the type that emits radio waves into space in response to electrical 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, solid radiation counter means provided with electrodes, means for connecting one of the electrodes to the antenna and another electrode to a section of antenna, and means for enabling the counter means to receive radiation and to produce an electrical impulse between the electrodes in response thereto in order to add or remove the section of antenna to and from the antenna to vary a dimension of the antenna during the emission of the radio waves by the antenna, thereby to effect modulation of the radio waves in accordance with the radiations detected by the radiation counter means.

5. A radio system for remoting radiation measurements having, in combination, a pair of radio-frequency conductors, an electric system for generating or receiving radio-frequency energy, means electrically connecting at least one of the conductors to the electric system in order that it may draw radio-frequency energy from or feed radio-frequency energy to the electric system, radiation counter means provided with electrodes, means for connecting one of the electrodes to one of the conductors and another electrode to the other conductor, 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 connect and disconnect the conductors in response to the radiations detected thereby during the drawing of the radio-frequency energy from or the feeding of the radio-frequency energy to the electric system.

6. A radio system having, in combination, an antenna having first and second sections for transmitting or receiving radio waves, an ionizable radiation counter having a pair of electrodes, means for connecting one electrode 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, thereby to signal-modulate the radio waves transmitted or received by the antenna.

7. A radio system having, in combination, antenna means comprising a plurality of successive antenna sections for transmitting or receiving radio waves, a plurality of gas-discharge elements each element of which is provided with electrodes and is responsive to different ionizing signals, each gas-discharge 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 gas-discharge elements 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 gas-discharge elements is ionized, thereby to effect dif-

ferent 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 different 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 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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