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R. S. OHL

2,378,944

DETECTOR SYSTEM FOR VERY SHORT ELECTRIC WAVES

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FIG. 1

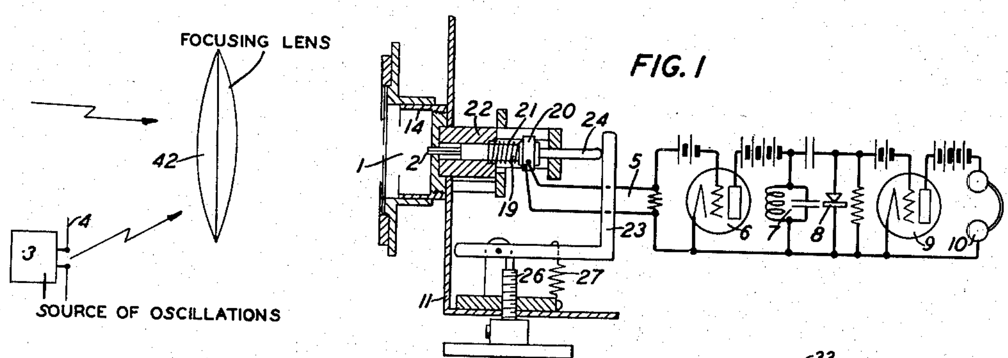


FIG. 4

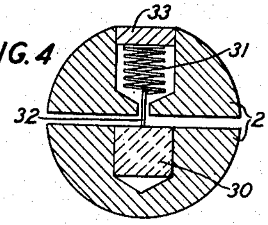


FIG. 2

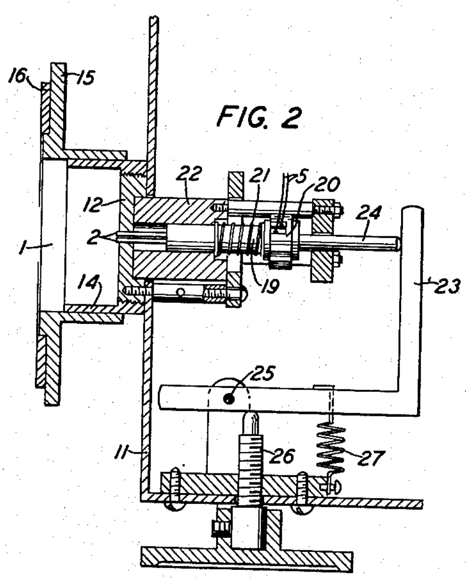


FIG. 5

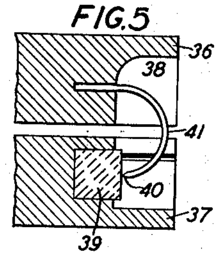


FIG. 6

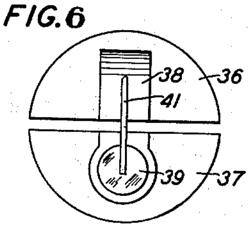
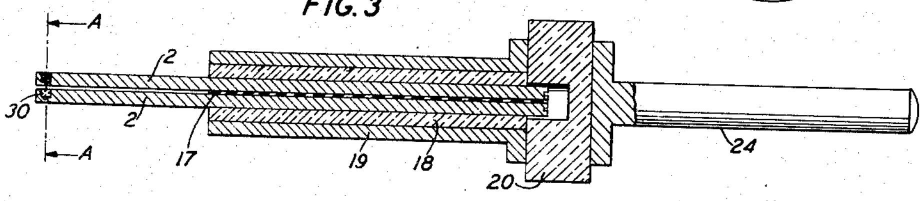


FIG. 3



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DETECTOR SYSTEM FOR VERY SHORT ELECTRIC WAVES

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10 Claims. (Cl. 250—20)

This invention relates to reception of high frequency oscillations and more particularly to receiving systems for selecting and detecting oscillations in the range of centimeter and millimeter wave-lengths.

An object of the invention is to provide an efficient selective absorbing system for very high frequency electromagnetic waves in space.

Another object of the invention is to provide a stable detecting system for oscillations of such high frequencies that electron discharge devices of the usual types are inffective.

The detection or measurement of electromagnetic waves in the centimeter and millimeter wave-lenth ranges requires apparatus sensitive at the frequencies involved and free from excessive capacitance. If the detection is to be preceded by a frequency selective operation, the selecting or tuning feature should preferably be of such character as not to greatly impair the sensitivity of the detecting system or to introduce excessive capacitance.

Hitherto the technique of electromagnetic wave reception has centered very largely about the electron discharge device which long ago superseded the early contact rectifiers or detectors of the general types developed by Dunwoody and Pickard. This change in radio reception practice was brought about by many factors among which are the amplifying property of the electron discharge device which enables the difficulties of weak incoming energy and of low detection efficiencies to be overcome, the high stability of the electron discharge device and the simplicity with which it lends itself to coupling to tuned or selective circuits.

As the technique of electromagnetic waves advances in the direction toward higher frequencies a point is reached at which the usual electron discharge device becomes comparatively ineffective. This point. which is somewhere in the region of 1000 megacycles, is set by inherent factors in the operation of these electron discharge devices such as the capacitance of the input circuit and the appreciable transit time of electrons as measured in cycles of the extremely high frequency oscillations. For such high frequency oscillations which are ordinarily of relatively low power it has been found that certain contact types of rectifiers are suitable as detectors. These devices have good conductivity in one direction and very little or no conductivity in the opposite direction. In general, the current passed by such devices increases as a complex exponential function of the increasing voltage but which, for practical purposes within relatively low ranges of applied electromotive force, may be regarded as having a square law characteristic. This is quite satisfactory for signal detection or for measurement purposes.

A contact rectifying device may, under certain conditions, be regarded as an asymmetric rectifier with a shunt path comprising series resistance and capacitance. The shunt path causes a decrease in sensitivity and a change in the exponetial response characteristic as the frequency is increased beyond certain limits. The high frequency limit at which a contact rectifier remains effective depends upon the area relations at the rectifying contact. For instance, if a point contact be made at an area which is wholly active, a very desirable characteristic may be obtained. If, on the other hand, the contact be made at an area which is partly active and partly inactive, the inactive portion will introduce an effective shunt path thus decreasing the sensitivity of the device as a whole. It has been found that by exploring the surface with a contacting point of a very small area as, for example, .04 square millimeter, while the rectifying device is subjected to a fairly high impressed alternating electromotive force, for example, 10 volts peak value, areas can be located which appear to be substantially wholly active. Accordingly, it is quite important that a rectifier to be used for this purpose be of such construction as will readily permit of a nice adjustment or variation of the contact area.

The general class of materials sometimes known as semiconductors such as iron-pyrite or semiconducting metals including boron, silicon, arsenic and tellurium are all stable in varying degrees for use in point contact detectors. When a current is drawn through a body of such a substance with one contact to the material large in area and very intimate while the other contact is relatively small and at a rather low pressure, an effect similar to a space charge effect is produced. That is, when a direct current passing through the contact in one direction is increased the resistance of the body drops, while, if current is caused to flow in the opposite direction, an increase in current causes the resistance to increase.

There is relatively wide choice of materials which may be employed to produce the desired rectifying effect. However, in addition to the rectifying effect there are a number of other important requirements for suitable materials in such detectors. Among these are stability of contact which depends upon the chemical inertness of the materials used and the mechanical design of the contacts. For example, the metallic oxides and sulphides which possess a rectifying property are generally either too soft as is the case of galena, a crystalline sulphide of lead, or are too chemically unstable. Another important characteristic is that the body possess a sufficiently low specific resistance. In the case of rutile, an oxide of titanium, the specific resistance is undesirably high. Another requirement is that the body have a satisfactory front-to-back resistance ratio or asymmetry of conductivity. The semi-metals which have been mentioned all have these characteristics in varying degrees and of them silicon appears to be fairly suitable. It is hard, inert chemically at low temperatures, not too high in specific resistance and has a satisfactory front-to-back resistance ratio. Applicant has discovered that this material has very desirable characteristics in rectification of extremely short electrical waves.

Another characteristic of interest in the performance of detectors of the contact rectifier type is the noise introduced by the detector. This is dependent upon the particular substance employed and also upon the amplitude of the currents to which the detector is subjected. For example, if a superheterodyne system with a beating oscillator is employed, the noise increases with the input of beating oscillations in such a way that for low levels of oscillation current the signal gain due to the increasing amplitude of the beating oscillations is more rapid than the increase in noise whereas for high levels of oscillation currents, the signal gain with increase of the beating oscillations is small but the noise increase is large.

Another important factor in the production of noise in the operation of a rectifying contact detector is the character of what we may term the "back contact." This is the contact which the semi-conductor body makes with the matrix of conducting material in which it is commonly embedded. If the back contact is somewhat imperfect the noise factor is high. If, on the contrary, the back contact is made with a matrix of conducting material which forms a substantially integral mass with the semi-conductor the noise is greatly reduced. Such a back contact may be secured in the case of silicon by electroplating the silicon body with chromium. In the case of iron-pyrite a similar low noise back contact may be attained by gold plating. These particular combinations of materials appear to make molecularly intimate contacts. If the semi-conductor body be so exceedingly small that it is impracticable to electroplate it a fairly satisfactory result may be had by dipping the unit in aquadag to form the back contact.

It has been found necessary not only to take into account the character of the body with which the contact is formed but, also, to employ a metallic point contact element which possesses certain characteristics. The point contact member should be inert chemically so that no oxide forms on its surface which might make possible a non-rectifying stable metallic contact. The point contact member must be ductile so that small wires of it are available and it must be strong and flexible enough to provide a contact having a steady pressure.

Accordingly, an additional object of the invention is to provide a metallic point contact with which it may be possible to assure uniform contact with the surface of the semi-metallic body and to adjust the pressure of the contact as desired.

It should be appreciated that the various characteristics and desirable properties which have been presented must, for practical use in the reception of millimeter-length waves, be attained in an apparatus of physical dimensions suitable for the reception of such waves and which is, therefore, of extremely small dimensions.

In accordance with the invention there is employed as a detector of very high frequency electrical oscillations a body of a substance such as the semi-conductors silicon or iron-pyrite connected in the high frequency oscillation circuit by one large back contact and one small rectifying contact which may be obtained at the tip of a very fine tungsten wire. The detector is preferably mounted between the open ends of two miniature Lecher circuit conductors which serve as the high frequency oscillation selecting circuit and, also, as the receiving antenna or electromagnetic wave absorber. Tuning is accomplished by variation of the position of a conducting plate or wall through which the high frequency short-circuited terminal ends of the Lecher circuit conductors extend. Surrounding the Lecher system is a conducting chamber of variable length for tuning purposes, one end of which is open to permit entrance of electromagnetic wave energy. At its open end the chamber is provided with an iris to determine the magnitude of the opening.

In the drawing:

Fig. 1 illustrates schematically a superheterodyne receiving set for electromagnetic waves of millimeter wave-length range;

Fig. 2 shows the frequency selective apparatus employed in the system of Fig. 1 as the receiving antenna and radio frequency selective circuit;

Fig. 3 illustrates details of the Lecher circuit constituting the receiving antenna of the apparatus of Fig. 2;

Fig. 4 is an enlarged sectional view in the plane A—A of Fig. 3 showing details of the detector;

Fig. 5 shows in longitudinal section, an alternative structure to that shown in Fig. 4, and

Fig. 6 is an end view of the detector of Fig. 5.

Referring to Fig. 1, the receiving apparatus for very short waves comprises a receiving chamber 1 constituted by electrically conducting surfaces and including a Lecher circuit 2 which serves as a receiving antenna for absorbing the energy of electromagnetic waves. The two semi-circular Lecher conductors 2 may be formed from wire of a highly conducting alloy comprising 70% gold, 25% silver, and 5% platinum. Connected to the antenna structure is a contact rectifier 30 (Fig. 3) which will be subsequently described. A local source 3 of low power oscillations differing in frequency from those to be received by a predetermined intermediate frequency serves in conjunction with its radiating antenna 4 to supply beating oscillations to the Lecher circuit 2. If desired, the source 3 may be connected to a small loop introduced directly into the chamber 1 by conductors passing through insulating sleeves in the wall of the chamber. The incoming oscillations which it is desired to receive, beating with the oscillations produced by source 3, yield intermediate frequency oscillations which are supplied from the Lecher circuit 2 by way of conductors 5 to the input circuit of intermediate frequency amplifier 6, the output circuit of which includes a resonant loop circuit 7 tuned to the intermediate frequency. A second detector 8 which may be of the iron-pyrite or silicon contactor rectifier type is connected across the tuned loop 7 and audio frequency demodulated waves in its output circuit are amplified by audio frequency amplifier 9 and supplied to the receiving instrument 10. A lens 42 of paraffin, beeswax, record wax or victron, may be employed to increase the energy input to the resonant chamber 1 by its focussing action.

Fig. 2 shows in more detail the receiving chamber and selective Lecher circuit antenna apparatus employed in the system of Fig. 1. A conducting casing 11 provided with an aperture through which the Lecher circuit conductors project, carries an annular conducting ring 12 of brass or other conducting material which serves as a high frequency short-circuiting member for the Lecher circuit conductors. The annular member 12 is spaced from the Lecher conductors just sufficiently to prevent its acting as a short-circuiting path for intermediate frequency oscillations. The capacitance between it and the conductors of the Lecher circuit is, however, sufficient so that the Lecher circuit is effectively terminated for millimeter-length waves at the outer face of the annular member 12. The member 12 is externally threaded to provide an adjusting feature for the tubular conducting shell 14 which projects forwardly from the casing 11 and carries at its open outer end a plate 15 on which is mounted the iris member 16. Inasmuch as the tubular member 14 may be adjusted to extend the chamber 1 in the axial direction of the Lecher conductors 2 and the iris 16 may be adjusted to fix the area of the opening into the chamber, it is possible to adjust or tune the system to respond most effectively to oscillations of a given wave-length by adjusting the tubular member 14 and to cause a maximum quantity of energy of oscillations of that wave-length to be absorbed by the Lecher conductors 2, by suitably varying the opening of iris member 16.

The Lecher conductors 2 are electrically separated by a strip 17 of mica or other dielectric material as illustrated in Fig. 3. A tubular sleeve 18 of dielectric material surrounds the Lecher conductors very closely to hold them firmly clamped together as a unit and is in turn enclosed in a tightly fitting metallic tube 19 a flanged end of which is attached to an enlarged circular dielectric block 20 having an opening at one side through which pass the leads 5 that connect the Lecher conductors to the external circuit. A helical spring 21 confined between the block 20 and the hollow guide 22 in which the tube 19 slides urges the block 20 and the entire Lecher circuit assembly to the right to withdraw it from the chamber 1 of shell 14. The position of the Lecher conductors is determined by a bell crank 23 bearing against the reaction bolt 24 and hinged at 25. The position of the bell crank is fixed by the adjusting screw 26 and the retracting spring 27. It is, therefore, possible to nicely adjust the position of the Lecher conductors with respect to chamber 1. In practice, the Lecher system is tuned to ¼ wave-length or ¾ wave-length as indicated by maximum response indications. The chamber 1 is adjusted in length to a multiple of a half wave-length as indicated by an incoming signal maximum. Finally the iris 16 is adjusted to obtain the most favorable impedance condition.

Fig. 4 which is a section in the plane 4—4 of Fig. 3, shows the structure of the contact rectifier-detector. It consists of a cylindrical block 30 of the semi-conducting material seated closely in a circular recess in one of the Lecher conductors. The other Lecher conductor is provided with an opening in which is inserted a spring 31, the end 32 of which presses down on the surface of the block 30 to make the rectifying contact. The spring 31 is held in position by a small plug 33 of electrically conducting material, fitting tightly in the hole and staked therein to secure the spring in position.

The block 30 may consist of any of a number of semi-conducting materials as has previously been explained. For low frequencies copper oxide is quite effective but its response falls off above the 60 to 70 kilocycle range and at two megacycles it is useless. Iron-pyrites is also effective and its effectiveness may be increased by electroplating the back surface with gold as has already been stated. Silicon, however, is preferable.

Since the detector is near the open end of the Lecher system it is at a point of substantially maximum voltage. The semi-circular Lecher conductors 2 extend back through the casing 11, and the annular member 12 as has previously been explained, is so nearly in contact with them that it serves as a short-circuiting path for high frequency energy thus determining the electrical tuning frequency of the Lecher circuit. Since the separation between the member 12 and the Lecher conductors is sufficient to maintain them electrically separated at the intermediate frequency, the beat frequency oscillations which result from interaction of the desired high frequency oscillations and the locally produced oscillations, are transmitted by the Lecher conductors back to the terminals 5 which pass out through the side of member 20.

An alternative form of detector is shown in Figs. 5 and 6 in which only the ends of the Lecher conductors which carry the members of the contact rectifier-detector are illustrated. The two Lecher conductors which may be of semi-circular cross-section as shown in Fig. 6 are designated by 36 and 37. A central recess 38 formed at the end of the two conductors is sufficiently deep to accommodate the detector members so that there may be no projecting portions which would interfere with precise tuning of the Lecher circuit. The detector consists of a cylindrical body 39 of semi-conducting material in contact with which is the tip 40 of a U-shaped contact wire 41, the base end of which is firmly fixed in the Lecher conductor 36.

The contact wire 41 of Fig. 8 and the spring contact member 31 of Fig. 4 both preferably consist of tungsten wire having its surface, and particularly its tip portion, coated with highly conducting material such as the alloy of gold, silver and platinum disclosed in U. S. Patent 937,284 issued October 19, 1909, to E. B. Craft and J. W. Harris, or with a platinum and iridium alloy. A contact wire of platinum-iridium alloy may also be used.

In an actual apparatus constructed in accordance with the disclosures of Figs. 2, 3 and 4 and designed to operate for reception of oscillations of 4 to 19 millimeters wave-length, the Lecher conductors 2 with their intervening mica strip 17 had a diameter of .053 inch. The silicon crystal employed as the element 30 of Fig. 4 was of cylindrical form with a diameter of .0173 inch and with a length equal to its diameter. The contact spring 31 was formed of seven or eight turns of .0009 inch diameter pure tungsten wire, gold-plated. This spring was wound on a form so made that a straight piece protruded from one end of the spring. This end was cut off with a small scissors.

The contact resistance between the silicon cylinder and its supporting Lecher conductor is reduced to a minimum by an aquadag coating on the cylinder. The tungsten spring wire 31 is carefully ground at the base end of the coil to have a large flat surface which may contact with the plug 33 at its base. The tungsten material of the spring wire 31 has sufficient torsional elasticity at the very small wire diameters employed to exert sufficient pressure on the crystal block to effect and maintain a satisfactory rectifying contact. The pressure, although not particularly critical, is, in general, so adjusted as to amount to about 250 grams per square centimeter.

What is claimed is:

1. In a receiving system for short waves, a tunable Lecher circuit serving as a selective electromagnetic wave energy-absorbing system and a rectifying contact detector connected thereto at substantially the maximum potential difference points of the Lecher circuit.

2. In a receiving system for short waves, a tunable Lecher circuit constituting an electromagnetic wave-absorbing antenna, a rectifying detector connected thereto at points between which there is a large difference of potential, an electromagnetic wave reflector surrounding the Lecher circuit and means for varying the length of the reflector to obtain maximum energy absorption at the Lecher circuit.

3. A receiving system for short waves comprising a tunable Lecher circuit constituting an electromagnetic wave-absorbing antenna, a rectifying detector connected to the Lecher circuit at points between which there is a substantial difference of potential, a variable length electromagnetic wave reflector open at one end surrounding the Lecher circuit and a variable iris member connected to the reflector at its open end to tune it for maximum energy reception by the Lecher circuit.

4. In a receiving system for short waves, a tunable Lecher circuit serving as an energy-absorbing device for incoming electromagnetic waves, a rectifying detector connected thereto at points between which substantially maximum potential difference exists and means for projecting locally generated oscillations of frequency different from the frequency of said incoming waves upon the Lecher circuit whereby the output of the detector contains a component of the difference frequency of the received electromagnetic waves and the locally generated oscillations.

5. In combination, a conducting chamber having an aperture to permit ingress of electromagnetic waves, a pair of Lecher circuit conductors projecting into the chamber through an aperture in the wall of the chamber, the wall of said second-named aperture being separated from the conductors by such a small spacing as to effectively short circuit the Lecher circuit at that point for extremely high frequency oscillations.

6. The combination of claim 5, characterized in this, that a rectifying contact detector is shunted across the Lecher circuit conductors at a point electrically remote from the wall through which they pass.

7. The combination of claim 5, characterized in this, that means is provided outside the wall of the chamber for varying the tuning of the Lecher circuit by varying the length of the Lecher circuit conductors extending into the chamber.

8. A receiving system for electromagnetic waves of the millimeter wave-length range, characterized in this, that the receiving antenna and the radio frequency selecting circuit comprise a pair of Lecher conductors of variable length disposed within an electrically conducting chamber which is closed except for an aperture for ingress of electromagnetic waves the pair of Lecher conductors extending through an aperture in a wall of the electrically conducting chamber, the margin of the aperture being so close to the Lecher conductors as to cause the capacitance between the wall and the Lecher circuit conductors to substantially short circuit the Lecher circuit at the frequency to which it is most highly responsive.

9. A receiving system for electromagnetic waves of extremely short wave-length, characterized in this, that two Lecher circuit conductors constituting the antenna and selective receiving circuit support between them a contact rectifier to set up in the Lecher circuit detected modulation currents corresponding to modulations of the received electromagntic waves.

10. A system for receiving and detecting electromagnetic waves of the order of millimeter wave-length comprising two closely spaced linear Lecher circuit conductors, the maximum dimension perpendicular to their lengths of which is of the order of .05 inch, each of said Lecher circuit conductors being recessed near one end on the face presented to the other conductor, a rectifying contact detector free from leads whereby substantially the full potential developed between said Lecher circuit conductors may be available for production of rectified current, the detector comprising a block of semi-conducting material seated in one of the recesses and a conducting spring member seated in the other recess and having a contact point in engagement with the surface of the block and means for tuning the Lecher circuit to enable it to respond most efficiently at a desired electromagnetic wave frequency, the ends of the Lecher circuit adjacent the recesses being insulated from all other conducting members whereby the Lecher circuit may develop a maximum open end potential across the contact detector.

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