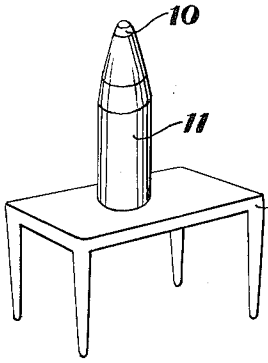
March 28, 1961 R. C. LOVICK 2,977,590

METHOD OF TESTING A PROXIMITY FUZE

Filed Feb. 12, 1953

Fig. 1



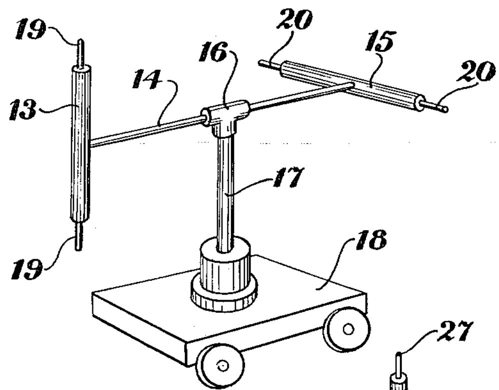
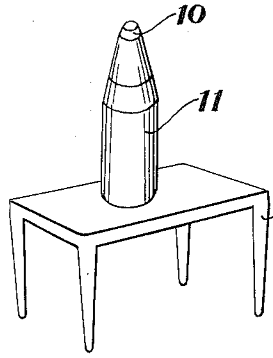
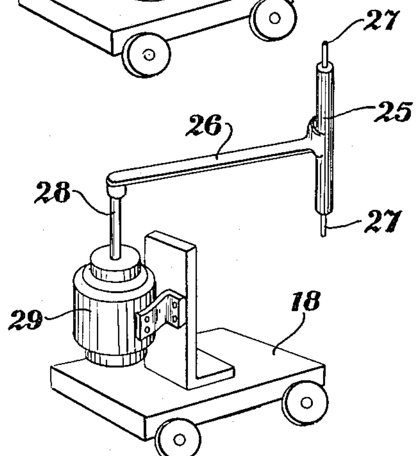


Fig. 2





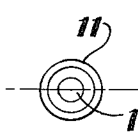
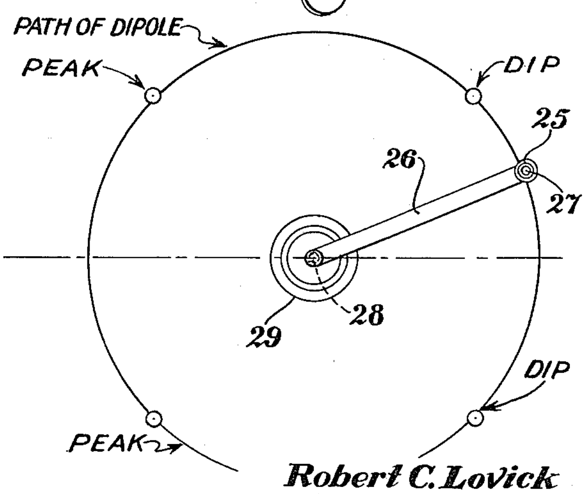


Fig. 3



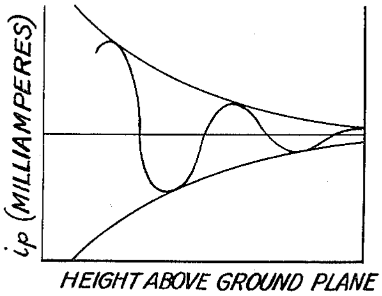


Fig. 4

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METHOD OF TESTING A PROXIMITY FUZE

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3 Claims. (Cl. 343—17.7)

This invention relates in general to electrical testing, and more particularly to apparatus for measuring the relative sensitivity of proximity fuzes for ordnance projectiles.

When an ordnance projectile equipped with a proximity fuze is fired from a gun, the oscillator of the fuze generates a continuous radio frequency signal. As the projectile approaches a reflecting surface, a portion of the energy radiated from the fuze is reflected back into the oscillator circuit of the fuze. As a result, the radiation load of the antenna of the fuze changes and varies through a series of maximum and minimum values of increasing magnitude as the reflecting surface is approached. Consequently, the current in the oscillator plate circuit rises and falls. A resistor in the oscillator plate circuit translates this rise and fall of plate current into a correspondingly fluctuating voltage. This voltage is applied through an amplifier to actuate a thyratron when the projectile comes within lethal range of the reflecting surface. The thyratron acts as an electronic switch to operate an electric detonator called a squib or booster. The blast from the booster operates an electrical detonating fuze which sets off the explosive charge in the projectile.

The change in the radiation loading of the fuze antenna, which in turn causes the oscillator plate current to rise and fall, is a primary factor in the ability of the fuze to function. The character of the fluctuations of plate current depends upon several factors, including the size and reflectivity of the target, oscillator frequency, velocity of approach, angle of approach, and the characteristics of the oscillator itself. However, if proximity fuze oscillators are subjected to standard conditions of antenna loading in a stable outdoor environment, and the electrical response of the oscillator to a standard change in such conditions is observed, the measurements will be an indication of the relative sensitivity of proximity fuze.

Such measurement, known as the pole test, is the primary method utilized heretofore to measure the sensitivity of the oscillator of proximity fuzes. In the pole test changes in the plate current of the oscillator are observed when a fuze mounted in a projectile shell is moved perpendicular to a large reflecting surface which is parallel to the axis of the shell. A proximity fuze is assembled within a test shell conforming in contour to the projectile shell in which the fuze is to be used. The test shell is supported above a metallic screen laid upon the ground by means of a suitable mechanism so that it can be raised and lowered, and the changes in the plate current of the oscillator are observed when the radiating shell is moved through the standing wave pattern caused by reflection from the screen. If the shell is slowly raised from the ground level, the oscillator plate current will be found to go through maxima and minima at certain distances above the ground, depending upon the frequency of the oscillator. For a grid detector oscillator a maximum of current will be

found approximately at ⅜λ above ground and a minimum at ⅝λ, the next maximum will be at ⅞λ and the next minimum at 1⅛λ. As the distance from the reflecting surface increases, the effect gradually dies out. The resulting steady plate current is equal to the plate current which would be that of free space loading, i.e., the value existing in the absence of any reflecting surface.

The shell can be considered as a small antenna radiating energy in the form of an electric field and a magnetic field. A portion of this energy is reflected when the antenna is brought near a reflecting surface such as the earth. The resultant of the incident and reflected electric field has nodes separated by one quarter wave length from the nodes of the resultant of the incident and reflected magnetic field. The total energy radiated for any given position of the oscillator is the cross product of the two and causes a minimum in oscillator plate current to occur at ⅛ wavelength, a maximum at ⅜ wavelength, a minimum at ⅝ wavelength, etc.

It is possible to indicate the sensitivity of the oscillator of a proximity fuze as a given change in plate current occurring between specified peaks and dips such as, for example, between 1⅜ and 1⅝ wavelengths above ground. However, the actual height above ground at which these points will occur will vary with frequency, so that sensitivity designated in this manner gives no information as to the sensitivity at a definite height. For this reason, the sensitivity of the oscillator of a proximity fuze has been defined as that at 15 feet above ground. The plate current is measured at a peak and a dip near fifteen feet and the result corrected to fifteen feet. The measured plate current I_p flows through a resistance R in the plate circuit of the oscillator, and the voltage developed is $I_p \times R$. Since the measured current is peak to peak value, and only the positive half of the voltage is required to fire the thyratron which detonates the booster, the voltage I_pR is divided by $2\sqrt{2}$ to obtain the sensitivity of the oscillator in root mean square amplitude. The distance of 15 feet is thus arbitrarily chosen at the point at which measurements will be taken statically to determine the relative sensitivity of proximity fuzes.

Because the pole test must be performed in a large flat area that is free from objects that might reflect the radiated waves, a location must normally be selected away from an urban area. The necessity of moving the fuzes from a laboratory to a distant field location for checking sensitivity is inconvenient and hampers experimental development. It is obvious that the inexpediency of having to send fuzes to a field location for measurement of sensitivity after every experimental change in construction necessitates a laboratory means of checking sensitivity. Such a secondary standard of measuring sensitivity would provide an accurate means of checking the basic testing done at the field pole.

Measurements of sensitivity taken by the pole test are particularly unreliable under conditions of inclement weather, particularly when snow covers the ground screen. The effect of absorption of the radiated energy by snow or moisture are not fully understood. The desirability of having a method to provide accurate measurements at other than the pole test site should be readily apparent.

It is an object of the invention to provide a convenient, accurate and rapid method of and apparatus for dynamically measuring the oscillator sensitivity of proximity fuzes.

This and other objects are obtained by assembling a proximity fuze within a specified vertical test shell and moving a vertical dipole antenna having a length approximately one half the wavelength of the energy radiated by the proximity fuze toward the shell from a point remote from the shell through one position wherein the energy reradiated from the dipole antenna produces a minimum of plate current in the oscillator of the proximity fuze to a second position wherein the energy reradiated from the dipole causes a maximum of oscillator plate current. The center of the reflecting dipole antenna is in the same horizontal plane as the electrical center of the radiating dipole of the proximity fuze. The amplitude of the observed ripple signal voltage variation between maxima and minima of oscillator plate current is an indication of the electrical sensitivity of the oscillator of the proximity fuze. This method of measuring the relative sensitivities of proximity fuzes will be referred to in the specification as the rotating dipole method.

Referring now to the drawings wherein like reference numerals designate like parts:

Fig. 1 is a schematic perspective view of one embodiment of the invention in which two dipole antennas are used;

Fig. 2 is a schematic perspective view of the preferred embodiment of the invention in which a single rotatable dipole is continuously moved into and out of the radiated field;

Fig. 3 is a diagrammatic plan view of the embodiment shown in Fig. 2; and

Fig. 4 graphically illustrates the changes in plate current with respect to height above ground.

To produce a system of dipoles which are positioned by distance and oriented on a rotating rod such that by rotating the rod through ninety degrees, the net effect is a measure of the sensitivity is disclosed in Fig. 1. The **fuze 10** is assembled in a projectile casing **11**, the casing being positioned on an insulating support **12**. A vertical dipole antenna **13** is mounted on one end of rod **14** and a horizontal dipole antenna **15** is mounted on the other end thereof. Rod **14** is rotatably mounted in bearing **16** on post **17** which is mounted on cart **18**. Each dipole antenna includes two metallic rods, rods **19** in antenna **13** and rods **20** in antenna **15**, which slidably telescope into the tubular portions thereof. The rods **19** and **20** can be extended to a position in which the overall length is approximately twice that of the cylindrical portion. This permits the adjustment of the length of the dipole antennas to half the wavelength of the waves radiated from fuze **10**. Antennas **13** and **15** are separated by a distance such that by rotating rod **14** through 90 degrees the dipole antennas are alternately coupled, this distance being approximately one quarter wavelength and producing a maximum and a minimum in plate current. With this arrangement dipole antennas **13** and **15** are alternately coupled thereby producing a minimum and maximum in plate current, the net effect being a measure of sensitivity and describing the entire curve of variation.

In the preferred embodiment of the invention illustrated in Fig. 2 of the drawings, a proximity fuze **10** is assembled in projectile casing **11**, casing **11** being positioned vertically on insulating support **12**. A single dipole antenna **25** is mounted in a vertical position at the end of rotatable horizontal arm **26** constructed of insulating material. The dipole antenna **25** consists of a hollow metallic tube having two metallic rods **27** slidably telescoped into the ends thereof. Rods **27** can be withdrawn to a position wherein substantially the full length of each rod extends beyond the ends of the antenna tube so that the length of antenna **25** can be increased to approximately twice the length of the tube. This permits the adjustment of the length of dipole antenna **25** to half the wavelength of the waves radiated from proximity fuze **10**. The horizontal arm **26** is attached to the upper end of the vertical shaft **28** of a motor **29** which may be mounted below the surface of the floor upon which support **12** rests to prevent reflection of the energy radiated

by proximity fuze **10**, in the event shaft **28** is fixed in position with respect to fuze **10**, or may be mounted on cart **18** and shielded to prevent reflection of the energy radiated by fuze **10**. The motor **29** is utilized to rotate the dipole antenna **25** at the end of horizontal arm **26**. The circular path traced by the dipole antenna **25** during rotation of horizontal arm **26** is shown in Fig. 3. In both embodiments of the invention, rod **14** and arm **26** are arranged in the radiating or electrical plane of fuze **10**.

The radiation pattern from the dipole of a proximity fuze is approximately at right angles to the plane of the axis of the fuze and encircles the fuze completely. The shape of the radiation pattern resembles a doughnut with the axis of the fuze passing through its center. When the axis of a fuze is vertical, the radiation is approximately equal in all directions in the horizontal plane while the vertical radiation along the direct line of the axis is substantially zero. The wave radiated from a vertical proximity fuze **10** is substantally vertically polarized.

A receiving antenna is able to abstract energy from a passing radio wave as a result of the voltage that the magnetic flux of the wave induces in the antenna. The value of the induced voltage is proportional to the field strength, the cosine of the angle between the plane of polarization of the wave and the wire in which the voltage is induced, and the cosine of the angle between the wave front and the direction of the wire. Thus a horizontal wire in the field radiated from a vertical proximity fuze will have a substantially zero voltage induced therein, while the voltage induced in a vertical wire will be a maximum.

The dipole antenna **25** absorbs power and reradiates it in a manner somewhat analogous to a parasitic reflector or a parasitic director. When the field produced by the dipole antenna of proximity fuze **10** cuts dipole antenna **25**, it induces a voltage therein which in turn produces a field which cuts the dipole of proximity fuze **10**. The dipole antenna **25** is not positioned at a fixed fractional wavelength from a driven antenna in the manner that a parasitic reflector is utilized, but in measuring oscillator sensitivity the dipole antenna **25** is moved from a position wherein the reradiated power cutting the dipole of proximity fuze **10** produces a minimum in oscillator plate current through a second position wherein the reradiated power causes a maximum of plate current. The dipole antenna **25** thus reflects the energy radiated from the dipole of the proximity fuze somewhat analogously to the manner in which standing waves are set up in a closed-end transmission line by reflection from the short-circuited end thereof. A portion of the energy radiated by proximity fuze **10** is reflected back by dipole antenna **25** into the oscillator circuit of the fuze. As a result, if a vertical dipole adjusted to approximately one half the wavelength of the radiated energy and not connected to a power source is positioned on movable cart **18** and advanced from a distant point toward a proximity fuze, the radiation load as seen by the dipole antenna of proximity fuze **10** changes, varying through a series of maximum and minimum values of increasing magnitude as the dipole approaches proximity fuze **10**. If in advancing a dipole antenna toward fuze **10** on movable part **18**, a point is found wherein the reradiated energy causes a node in oscillator plate current, then the distance between the axis of casing **11** and motor **29** is adjusted until shaft **28** is approximately at this point and motor **29** is controlled so as to rotate horizontal arm **26** slowly. At this point the plate current of the oscillator will vary from a minimum to a maximum and from a maximum to a minimum in the same manner as when the fuze is raised from and lowered toward the ground screen in the pole test.

Fig. 4 illustrates the changes in plate current observed by the pole test when a fuze, mounted in a test shell, is moved perpendicular to a large reflecting surface which is parallel to the test shell axis. Such a diagram is spoken of as a "ripple pattern." The changes in plate current are made readily measurable by bucking out the steady plate current of the oscillator, leaving only the plate current fluctuations to be observed on a sensitive meter.

As described hereinbefore, the sensitivity of the oscillator as determined by the pole test has been arbitrarily defined as a given change in plate current at a definite height above ground in order to allow comparison of the relative sensitivities of proximity fuze oscillators. The plate current variations observed by the rotating dipole method when antenna **25** is rotated by motor **29** also provides a direct indication of the relative sensitivity of a proximity fuze oscillator. Sensitivity measured by the rotating dipole method is best defined as the root mean square amplitude of that cycle of the alternating current ripple signal voltage which encompasses a point on a plane at a fixed distance from fuze **10** as dipole antenna **25** is moved toward the shell. Experiment has shown that the position of the dip and the peak are not an exact number of ⅛ wave lengths from the axis of the shell, and that the position of the peak and dip vary somewhat with the length of dipole antenna **25**. Although changing the dipole length varies the position of the dip and peak, the total voltage excursion remains approximately constant. This provides a rapid and reliable method of checking sensitivity measured by the pole test.

Although the rotating dipole method can be carried out in a room that will not reflect energy radiated by proximity fuze **10**, the most accurate results are obtained if the apparatus is located on the roof of a building where no reflection from side walls is possible. Also, to obtain more accurate results, the casing should be placed at a convenient distance from the floor or roof level. Any horizontal metallic objects, such as pipes that might act as reflectors of the energy radiated from a vertical proximity fuze are in a plane where such metallic objects will have substantially zero voltage induced therein and, consequently, will re-radiate only a minimum of power.

To utilize the method of the invention to check the readings of proximity fuze sensitivity measured by the pole test, it is desirable to adjust the distance between the axis of casing **11** and the shaft **28** so that the rotation of dipole antenna **25** will produce plate current variations which numerically approach the readings obtained by the pole test. The sensitivity of the oscillator of a proximity fuze has been arbitrarily defined as the amplitude of the cycle of ripple voltage signal which encompasses a point fifteen feet from the ground screen as the shell is moved perpendicular to the ground screen. If a dipole antenna is supported upon movable cart **18** and advanced from a remote point toward the proximity fuze **10**, the oscillator of fuze **10** will vary through a series of maxima and minima of increasing amplitude as dipole **25** approaches casing **11**. The amplitude of one cycle of oscillator plate current variation will approximate within five percent the amplitude of plate current variations obtained by the pole test at fifteen feet from the ground screen, e.g., the oscillator plate current variation may have been found to be 92.2 micro-amperes at 15 feet by the pole test, while 88.3 micro-amperes swing may have been the closest numerical value measured between a peak and a dip as the dipole approaches casing **11**. The oscillator plate current variations measured by the rotating dipole method will never read exactly the same as the pole test measurements. A factor of proportionately must always be used to correct the readings obtained by the rotating dipole method, i.e., it will be necessary to calibrate the apparatus embodying the invention to the pole test. However, once the rotating dipole is calibrated for a given frequency range, sensitivity measurements can be made directly without the necessity of moving the dipole from a remote point toward the proximity fuze to establish the cycle wherein the amplitude of the voltage swing most closely approximates the pole test measurement of sensitivity. Once the position of the motor shaft **28** is fixed for any given range of frequencies it is only necessary to multiply the plate current variation obtained by the rotating dipole method by the constant of proportionality obtained in the calibration to obtain a reading directly indicative of the sensitivity measured at fifteen feet by the pole test.

A tolerance of plus or minus a few megacycles in the frequency of oscillation is usually provided in the production of proximity fuze oscillators. If the length of dipole **25** is once adjusted for the mean frequency of the allowable spread of oscillator frequency, the dipole system will give repeatable results within the ability of the field pole to reproduce. As dipole **25** is slowly rotated by motor **29**, the oscillator plate current of proximity fuze **10** will vary from a minimum, or dip, to a maximum, or peak, and from a peak to a dip in a continuous motion. The readings of plate current variation when divided by $2\sqrt{2}$ and multiplied by the factor of proportionality obtained during the calibration of the dipoles will give a direct indication of pole test sensitivity. It is not necessary to vary the length of dipole antenna **25** for each different proximity fuze **10** which is inserted within the shell casing **11** for check of oscillator sensitivity. If dipole antenna **25** is adjusted for the mean frequency of a normal production run of frequencies, the dipole system embodying the method of the invention will give repeatable results within the ability of the pole test to reproduce. The criticalness of the length of dipole **25** is reduced if the dipole is relatively thick. Increasing the thickness decreases the Q of dipole **25**, so that the length of the dipole is particularly unimportant when a relatively thick dipole antenna is utilized.

As described hereinbefore, the oscillator sensitivity of a proximity fuze is arbitrarily defined at a distance of fifteen feet from a ground screen. It is possible to utilize this apparatus as a primary standard for measuring oscillator sensitivity of proximity fuzes. This is best accomplished by defining oscillator sensitivity as the change in ripple signal voltage occurring between specified peaks and dips such as, for example, between a dip when the distance between reflecting dipole antenna **25** and proximity fuze **10** is $2\frac{5}{8}\lambda$ and a peak when this distance is $2\frac{3}{8}\lambda$. Oscillator sensitivity indicated in this manner is not in terms of pole test measurements but directly in terms of ripple signal voltage variations occurring when a reflecting dipole is moved between specified peaks and dips. In using a reflecting dipole antenna in this manner as a primary standard, it is unnecessary to change the length of dipole antenna **25** or the distance between the dipole and fuze **10** for each measurement of sensitivity. The length of antenna dipole **25** is adjusted for the mean frequency of the allowable tolerance spread of frequencies in a manner similar to that described when the dipole method is used as a secondary standard for the pole test. The distance between fuze **10** and shaft **28** is adjusted so that reflecting dipole antenna **25** in rotating at the end of the horizontal arm **26** moves through positions causing the peak and dip in terms of which the oscillator sensitivity has been defined, e.g., through a point $2\frac{5}{8}\lambda$ from fuze **10** causing a dip in the oscillator plate current and a second point $2\frac{3}{8}\lambda$ from fuze **10** causing a peak in plate current. The readings of oscillator plate current for each projectile tested (when converted to voltage indications by multiplying by the resistance on the oscillator plate circuit and dividing by $2\sqrt{2}$) are obtained by connecting an electronic voltmeter across the plate circuit of the oscillator in a well-known manner and are thus direct measurements of the relative sensitivity of proximity fuzes and are repeatable within the limits of accuracy that the field pole test can reproduce.

Whenever it is necessary to calibrate the diploe method for a new range of frequencies, it is necessary to employ a movable cart to trace the ripple pattern just as in the original calibration. Moving reflecting dipole 25 on cart 18 from a remote point toward radiating fuze 10 will cause the oscillator plate current to vary through the ripple pattern and allow the determination of the distance between fuze 10 and shaft 28 which will permit dipole antenna 25 to move through the specified dip and peak when rotated at the end of the horizontal arm 26, e.g., through a point 2⅝λ from the axis of casing 11 causing a dip in oscillator plate current and also through a second point 2⅜λ from fuze 10 causing a peak in oscillator plate current. If the length of dipole antenna 25 is adjusted to the mean frequency of the range of frequencies allowable in production, direct readings of the relative sensitivity of oscillators within this frequency range can be made directly by the rotating dipole method.

I claim:

1. The method of measuring the sensitivity of the oscillator of a proximity fuze which is adapted to radiate a radio frequency wave generated by said oscillator and substantially polarized in the plane of the axis of said fuze when said fuze is electrically actuated which comprises assembling the proximity fuze in a vertical projectile shell in a location remote from vertical objects that reflect radio frequency energy, positioning the center of a vertical dipole antenna in substantially the same horizontal plane as the electrical center of the proximity fuze, electrically actuating the fuze, adjusting the length of said dipole antenna to approximately one half the wavelength of the radiated radio frequency energy, moving the dipole into said radiated wave whereby the dipole will reflect the energy radiated from said fuze and the standing wave resultant of the radiated and reflected radio frequency energy will cause the plate current of said oscillator to vary between a series of maxima and minima of increasing magnitude as the dipole approaches the fuze, and then measuring the amplitude of the fluctuations of oscillator plate current.

2. The method of measuring the sensitivity of the oscillator of a proximity fuze which is adapted to radiate a radio frequency signal generated by the oscillator and substantially polarized in the plane of the axis of the fuze when said fuze is electrically actuated which comprises assembling the proximity fuze in a vertical projectile shell in a location remote from vertical objects that reflect radio frequency signals, mounting a rotatable vertical dipole antenna with its center in substantially the same horizontal plane as the electrical center of the fuze and at a distance from the axis of the fuze equal to a number of one-eighth wavelengths of the radiated radio frequency signal so that said dipole is coupled to said fuze and the standing wave resultant of the radiated signal and the signal reflected by said dipole causes a maximum to occur in the plate current of the oscillator

of the fuze, mounting a rotatable horizontal dipole antenna with its center in said horizontal plane and in the plane defined by the axis of the fuze and the center of said vertical antenna and with a separation between the two dipoles of approximately one-quarter wavelength of said radiated signal, adjusting the length of both dipole antennas to approximately one-half of said wavelength, electrically actuating said fuze, rotating said vertical dipole antenna to a horizontal position to uncouple said vertical dipole, rotating said horizontal dipole to a vertical position to couple said horizontal dipole to said proximity fuze to cause a minimum current flow in the oscillator plate, and then measuring the amplitude of the cycle of oscillator plate current from said maximu to said minimum.

3. The method of measuring the sensitivity of the oscillator of a proximity fuze which is adapted to radiate radio frequency energy substantially polarized in the plane of the axis of the fuze when the fuze is electrically actuated which comprises assembling a proximity fuze in a vertical projectile shell in a location remote from vertical objects that reflect radio frequency energy, mounting a vertical dipole antenna with its center in substantially the same horizontal plane as the electrical center of the fuze and at the end of a rotatable horizontal arm of greater length than one-eighth the wavelength of said radio frequency energy, adjusting the length of the dipole antenna to approximately one-half the wavelength of said radio frequency energy, electrically actuating said fuze, and slowly rotating said dipole antenna with the axis of rotation of said arm positioned approximately a plurality of quarter wavelengths of said energy from the axis of the fuze whereby the standing wave resultant of the radiated energy and the energy reflected by said dipole antenna will cause the plate current of the oscillator of said fuze to vary from a maximum to a minimum and from a minimum to a maximum in one complete rotation of said arm, and then measuring the amplitude of one cycle of the standing wave of the oscillator plate current from said maximum to said minimum.

References Cited in the file of this patent

UNITED STATES PATENTS

1,756,462	Jenkins	Apr. 29, 1930
1,942,594	Edwards et al.	Jan. 9, 1934
2,103,357	Gerhard	Dec. 28, 1937
2,169,374	Roberts	Aug. 15, 1939
2,189,582	Hineline	Feb. 6, 1940
2,248,599	Alexanderson	July 8, 1941
2,279,695	Secretan et al.	Apr. 14, 1942
2,422,382	Winchel	June 17, 1947
2,715,725	Jackson	Aug. 15, 1955
2,727,140	Bell	Dec. 13, 1955