United States Patent

[11] 3,610,920

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[54] **APPARATUS AND METHOD FOR DERIVING A UNIFORM TIME WARNING**
16 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **246/128,** 246/122
[51] **Int. Cl.** **B61l 1/02**
[50] **Field of Search** .... 246/125–130, 34 CT, 122

[56] **References Cited**

UNITED STATES PATENTS

3,035,167	5/1962	Luft	246/130
3,246,142	4/1966	Steele et al.	246/128
3,246,143	4/1966	Duckitt et al.	246/34 CT
3,450,874	6/1969	Whitten	246/34 CT

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ABSTRACT: An improved warning system has been provided for activating crossing signal as a function of train speed. A transmitter coupled to the rails generates an input signal which is modified by the shunting of the rails by the railroad vehicle wheels. A receiver coupled to the transmitter through the rails converts the modified signal into a receiver signal. The improvement for providing a uniform warning time includes a detector which periodically samples the receiver signal and provides an output signal for energizing the crossing signal when the difference between any successive pair of samples is greater than a predetermined value indicative of the uniform warning time. The amplitude of the receiver signal decreases logarithmically as the train approaches the crossing. The variation provides a characteristic to the system such that for increasing vehicle speeds the crossing signal is activated at increasing vehicle distances from the crossing such that the warning time is substantially the same for any vehicle speed. The logarithmic variation is achieved by selective impedance manipulation of the coupling between the transmitter and receiver.

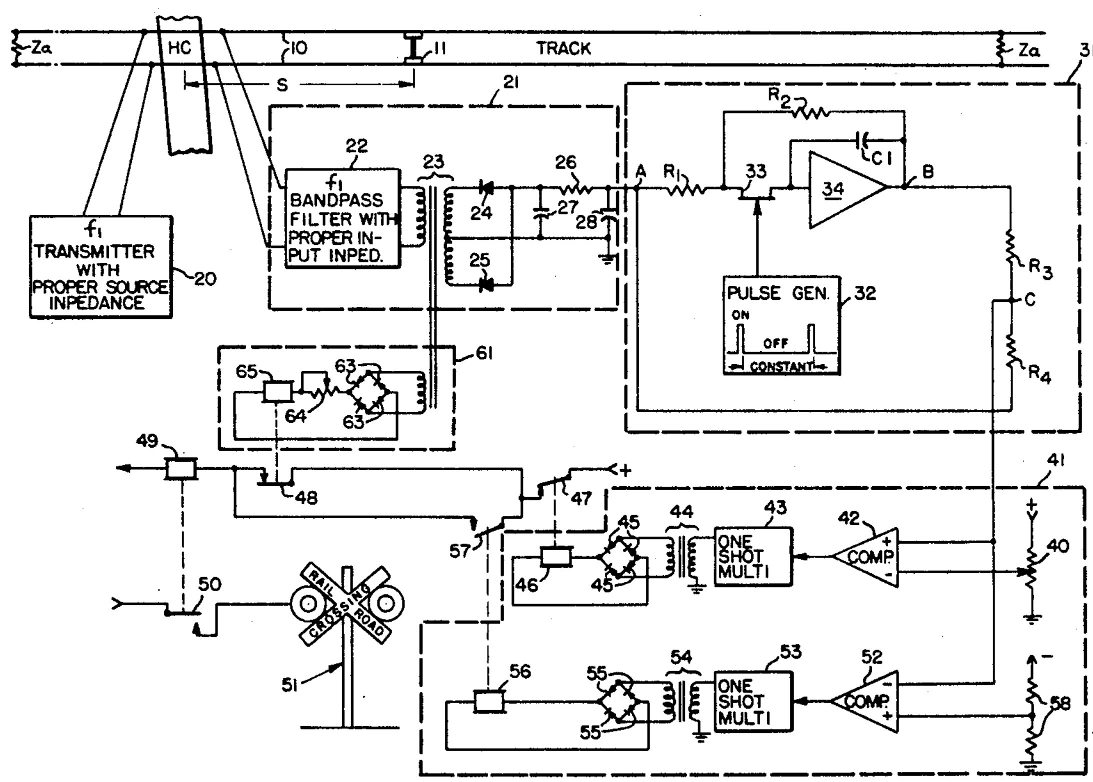


FIG. 1

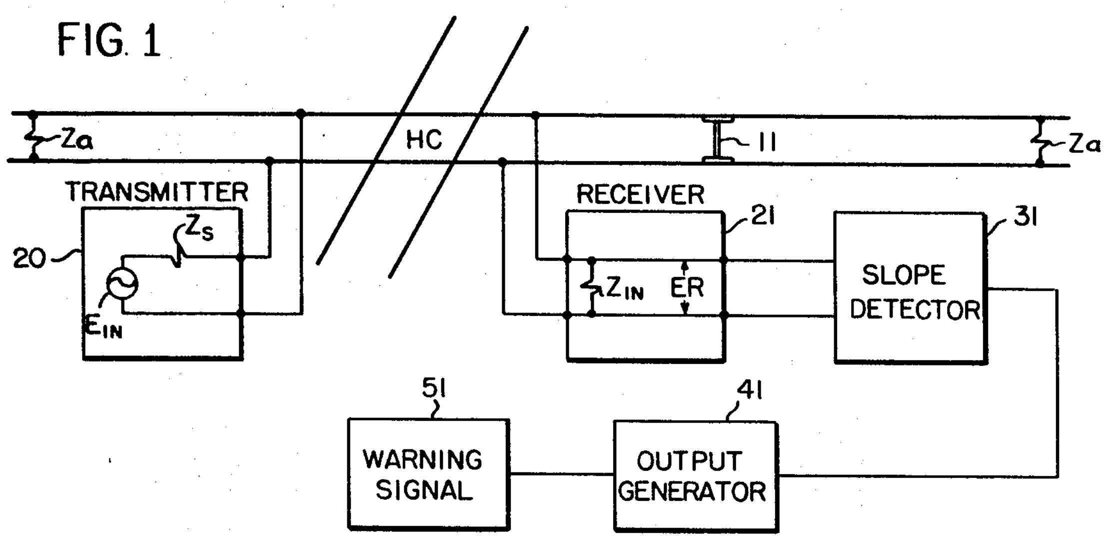
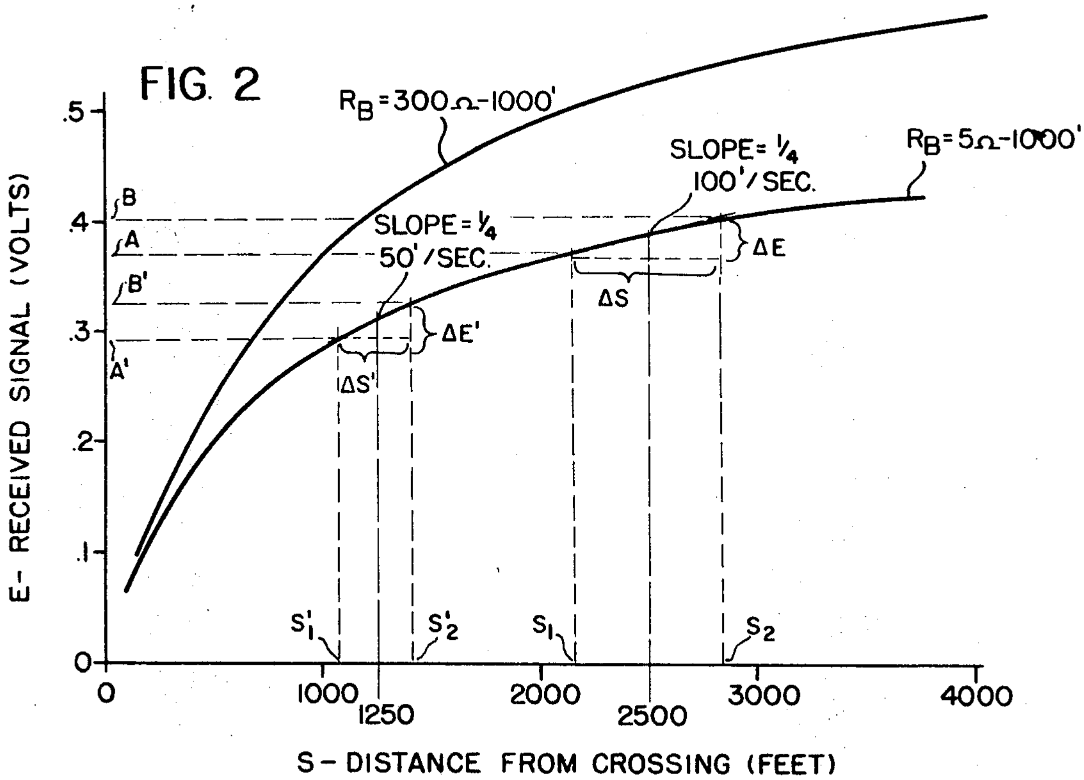


FIG. 2



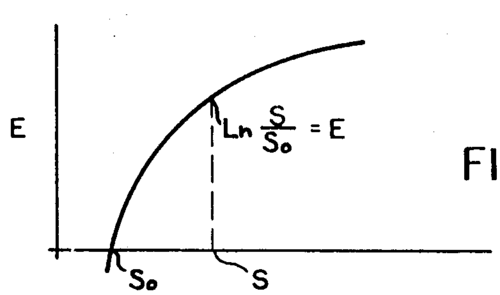


FIG. 3

FIG. 4B

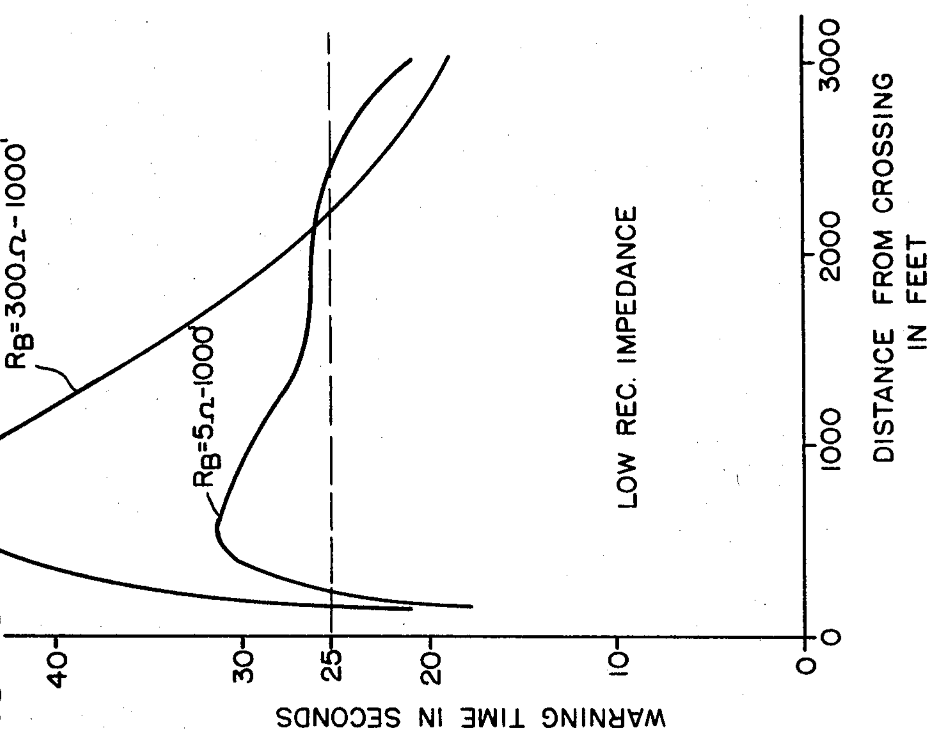
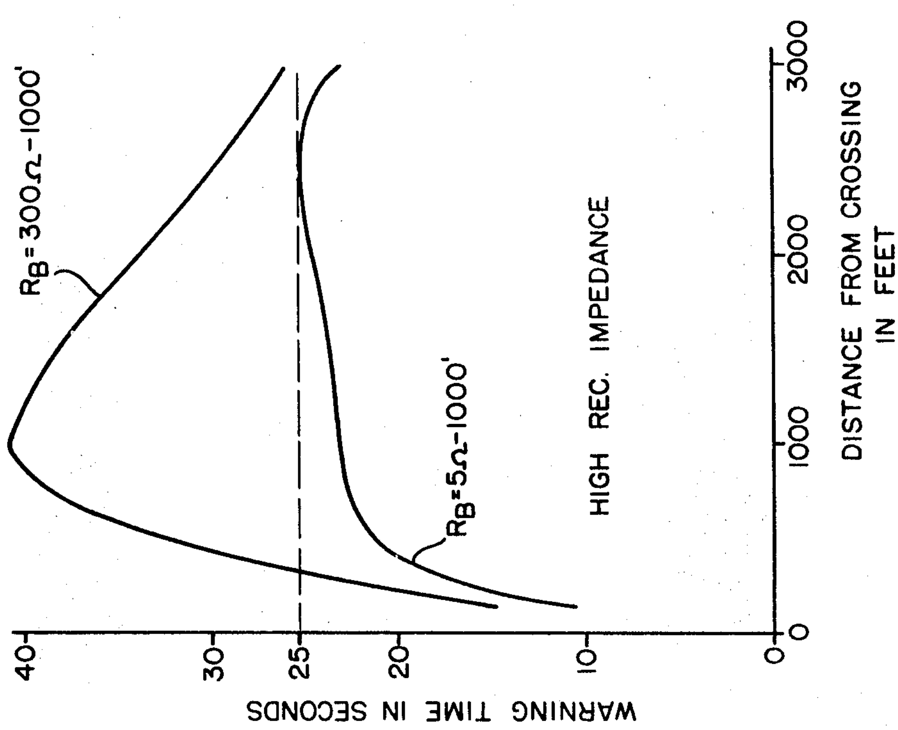

R_B=300Ω-1000'
R_B=5Ω-1000'
LOW REC. IMPEDANCE
WARNING TIME IN SECONDS
40
30
25
20
10
0
0
1000
2000
3000
DISTANCE FROM CROSSING IN FEET

FIG. 4A


R_B=300Ω-1000'
R_B=5Ω-1000'
HIGH REC. IMPEDANCE
WARNING TIME IN SECONDS
40
30
25
20
10
0
0
1000
2000
3000
DISTANCE FROM CROSSING IN FEET

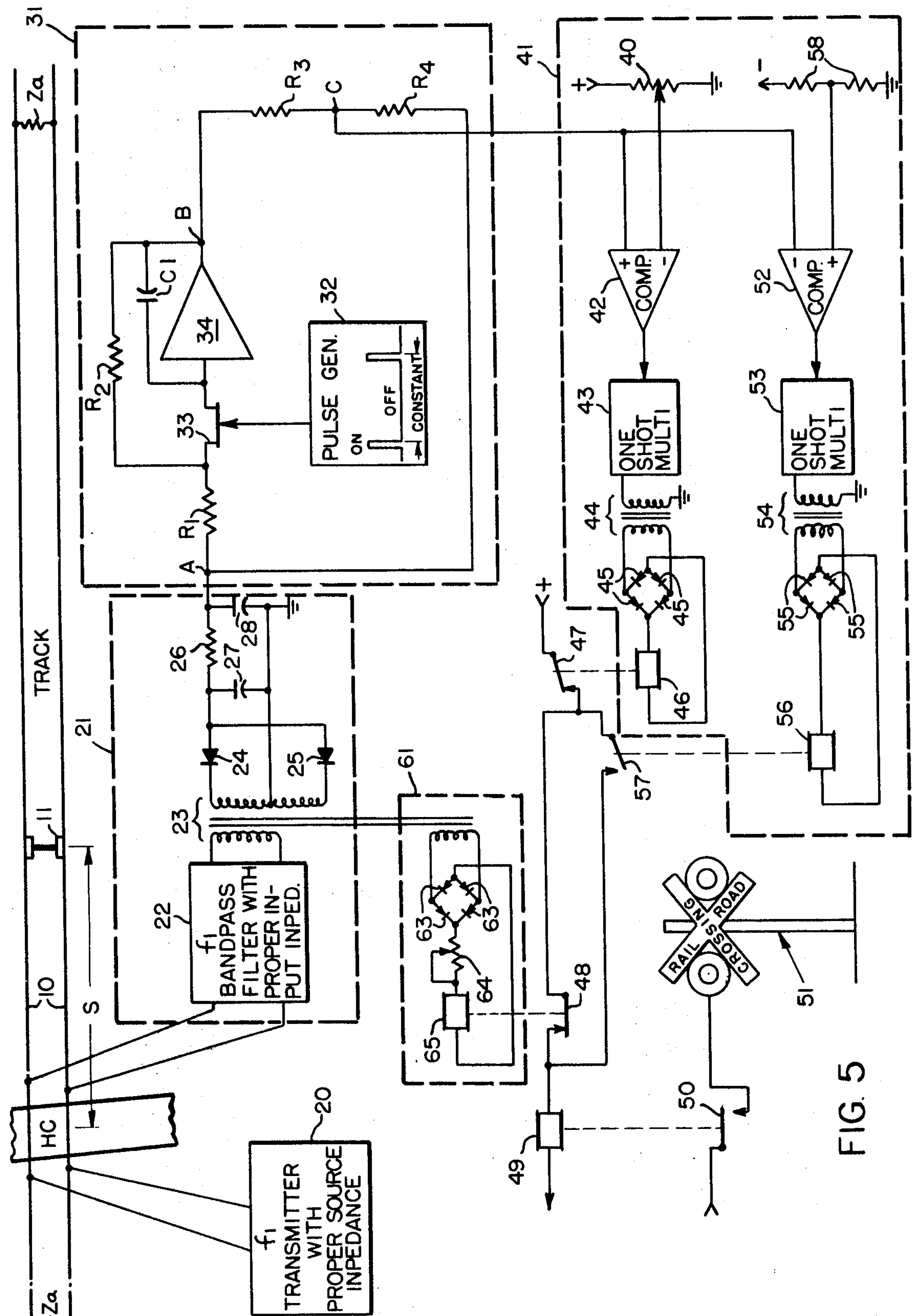

TRACK
Za
Za
HC
S
f_1 TRANSMITTER WITH PROPER SOURCE INPEDANCE
f_1 BANDPASS FILTER WITH PROPER IN-PUT INPED.
PULSE GEN.
ON
OFF
CONSTANT
COMP.
COMP.
ONE SHOT MULTI
ONE SHOT MULTI
RAIL ROAD CROSSING

FIG 5

FIG. 4D

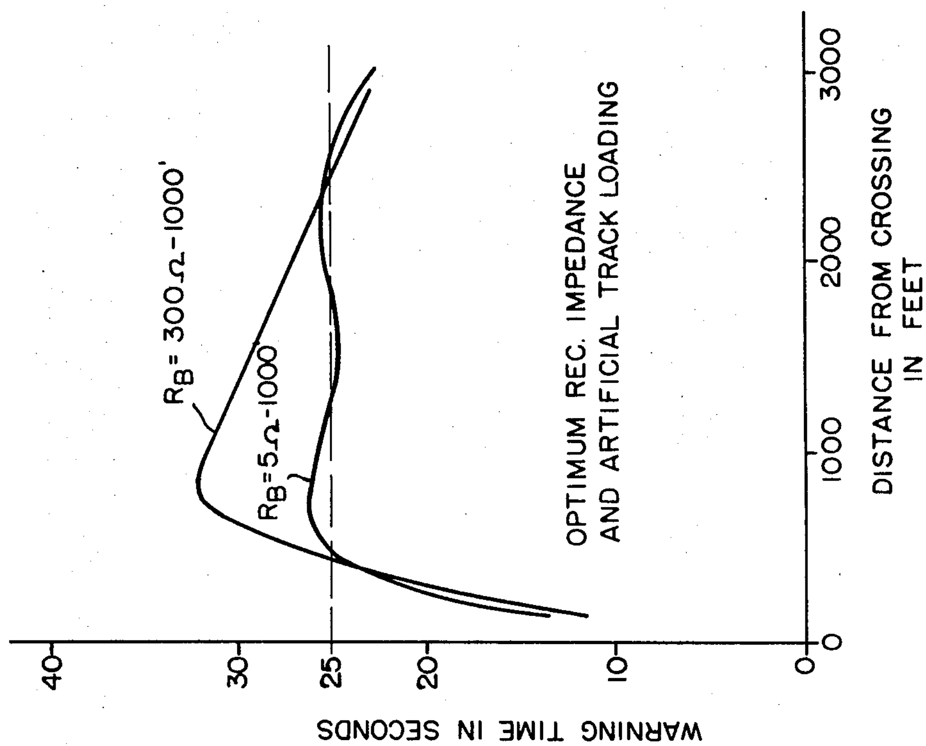
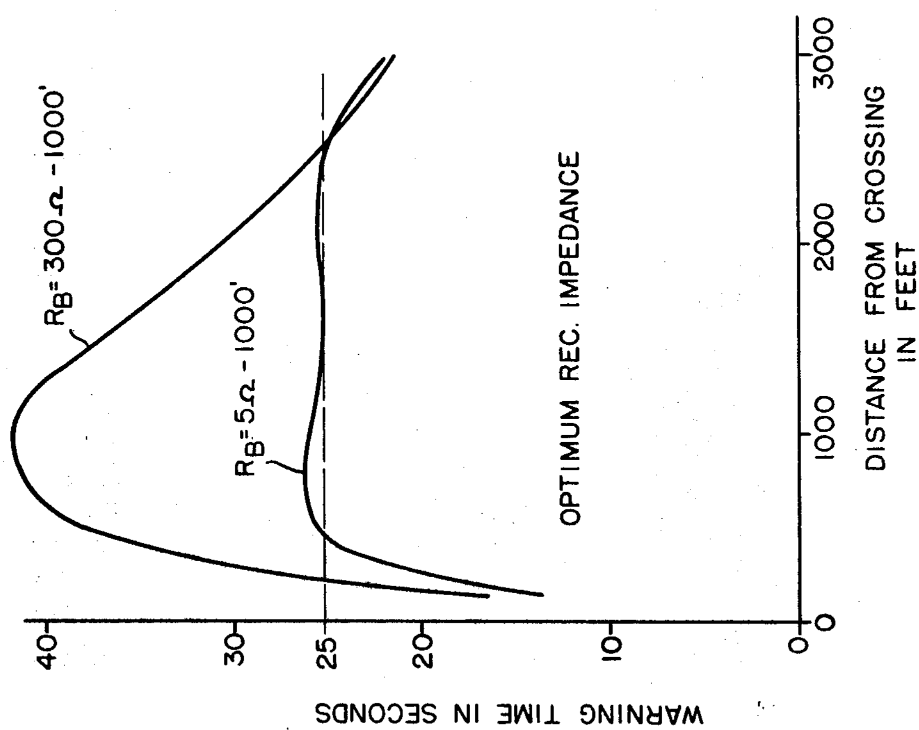

R_B = 300Ω-1000'
R_B=5Ω-1000'
OPTIMUM REC. IMPEDANCE
AND ARTIFICIAL TRACK LOADING
WARNING TIME IN SECONDS
40
30
25
20
10
0
0
1000
2000
3000
DISTANCE FROM CROSSING
IN FEET

FIG. 4C


R_B= 300Ω -1000'
R_B=5Ω -1000'
OPTIMUM REC. IMPEDANCE
WARNING TIME IN SECONDS
40
30
25
20
10
0
0
1000
2000
3000
DISTANCE FROM CROSSING
IN FEET

APPARATUS AND METHOD FOR DERIVING A UNIFORM TIME WARNING

BACKGROUND OF THE INVENTION

This invention relates to highway grade-crossing protection and in particular to an improved system for providing a uniform warning time at the crossing for trains of various speeds.

Highway crossing protection systems present problems which require study in the area of fail-safe operation, economy of installation and maintenance and efficiency of operation. The parties involved in the decision as to when and where to install such crossing protection are concerned with the amount of equipment necessary for the proper operation of the system and balancing of certain criteria including the safety provided by a grade-crossing protector and the cost of installation. Systems of this type must also be efficient in operation; that is, they must not only operate properly all the time but reduce to a minumum the delay to cross traffic. Generally, the way to prevent long delays at a crossing is to provide s uniform warning time; that is, for any vehicle within a foreseeable range the crossing signal will be activated a given number of seconds before railroad vehicle reaches the crossing so that the cross traffic will have a chance to clear the tracks and the highway will be blocked for a minimum amount of time. Some systems use multiple sections of track and roughly compute the warning time by using timing sections and the like. However, the installation and maintenance of such systems is quite expensive and the protection afforded in terms of its accuracy is not necessarily justified. Some systems have a section of track insulated from the main line which is shunted as soon as the train enters the section and a device responsive to the shunt activates the signal immediately. Such a system works well for fast-moving trains because track section must be long enough to provide an adequate warning time. However, slow trains activating the signal upon entering a long section produce an inordinately extended warning time. In such a case, the traffic at the crossing is delayed for an unnecessary amount of time and motorists who may be waiting at the crossing will attempt, no doubt, to cross against the prohibition of the signal. This also occurs when a train stops within a track circuit and starts up again. The purpose of the signal, therefore, is defeated if it is disobeyed. Numerous accidents have occurred where motorists disregard such signals because of lack of patience.

Other systems in use compute the distance that the train is from the crossing by measuring the impedance across the rails as the train moves towards the crossing. A change in impedance occurs because the wheels shunting the rails move towards the crossing. The rails are treated as analogous to a transmission line. This type of system has proven effective because it can provide a generally uniform warning time and is compatible with present track systems using coded information. Such a system does not necessarily require insulated track circuit sections and therefore the necessity of providing AC bypass of such insulated sections is obviated reducing substantially the cost of installation. The system itself can be located entirely at the crossing with connections to the rails simply installed. The advantages therefore in terms of ease of installation, maintenance and accuracy are quite important.

Certain problems however have been observed in the application of such a system. For example, the complexity of the circuits involved has had to be increased in order to reduce some problems associated with noise and effective range of the system as a whole.

Systems employing apparatus for determining the uniform warning time operate generally on the principle that the instantaneous position of the shunt at any time defines the impedance of the tracks. This value of impedance changes as the train moves toward the crossing. The rate of change of impedance is correlated to the velocity of the train and this information is operated upon by an analog computer to calculate the point in time to activate the warning. A signal is impressed

upon the rails and for each position of the train with respect to the crossing a different amplitude signal is received by a receiver. The signal indicative of the position of the train (i.e. impedance of the rails) is then differentiated yielding a signal representative of the velocity. If additional information is necessary, that is, acceleration, the velocity signal is differentiated to give this value. The signals obtained from the various steps of differentiation are operated upon to produce a solution to the equation of a linearly moving object. This information is then compared with a preset value which is correlated to the uniform warning time. The prediction equation is solved with the uniform time inserted, and the warning device is activated upon satisfaction of the equation. Such an apparatus, however, requires a number of amplifier circuits to achieve the results required.

Another problem which bears more explanation is that involving track circuit length. It has been observed that as the length of track circuit increases, the reflected signal from a shunt across the rails reaches a maximum at some point and then begins to decrease as the shunt is moved farther away from the crossing. It is undesirable for this to occur because the effective range of the system is drastically reduced. It is quite necessary for the reflected signal to reach its maximum at a distance from the crossing long enough to accommodate rapidly moving trains.

In order to further reduce delays, means must be incorporated for detecting when a train stops before the crossing. In addition, as soon as the last car passes the crossing, the signals must be extinguished and as the system of the present invention does not require insulated joints at the crossing, a means responsive to the departing train must be included.

It is therefore the intention of this disclosure to provide a system which is economical in its required apparatus.

It is another object to provide a system which will operate effectively over long track circuit lengths.

It is yet another object of the invention to provide a system which will yield a substantially uniform warning time.

It is another object of the invention to provide a simple apparatus for the calculation of the uniform warning time.

The foregoing and other objects and advantages of the invention will become apparent from the following description when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram of the preferred embodiment of the invention.

FIGS. 2, 3 and 4 A–D are curves to be used in the description of the preferred embodiment and the theory of the operation of the invention.

FIG. 5 is a partial block, partial schematic diagram of the preferred embodiment of the invention.

There has been provided an improved system for activating a railroad crossing signal as a function of train speed. The system includes a transmitter coupled to the rails for impressing an alternating current input signal thereon in the vicinity of the crossing. The input signal is modified by the movement of railroad vehicles along the rails by attenuating the input signal as the vehicles approach the crossing. A receiver is coupled to the rails near the crossing and is responsive to the magnitude of the modified signal. The receiver initiates a triggering signal for energizing the crossing at a time when the rate of variation of the modified signal achieves a preset value. The improvement for providing the uniform warning time includes, a detector in the receiver which responds to the rate of variation of the modified signal and produces the triggering signal when the rate of variation reaches the preset value. Impedance-compensating means, couples the output and input of the transmitter and receiver respectively in order to influence the variation of the modified signal so that it varies substantially at an exponential rate. At various vehicle speeds the modified signal achieves the preset rate and the warning is activated at a uniform time prior to the vehicle's arriving at the crossing.

There has also been provided a method of deriving a uniform warning time wherein a signal imposed on the rails and modified by railroad vehicle movement thereon is sampled at a periodic rate for detecting the slope characteristic thereof. When the slope achieves a preset rate, a warning signal is activated. Selective impedance adjustment coupling the impressed signal and the sampled signal constrains variation of the impressed signal to a substantially logarithmic rate so that for various vehicle speeds the signal reaches the preset slope at a uniform time before the vehicle reaches the crossing.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention described herein is intended to provide a system wherein a highway crossing warning system is activated a fixed number of seconds before the train enters the crossing regardless of speed. In case the train stops before it enters the crossing, it releases the crossing to vehicular traffic, but when the train starts up again, the highway crossing warning system is again initiated a fixed number of seconds before the train enters the crossing. As the end of the train clears the crossing, the crossing signal is extinguished. Should the train stop and back up on the highway, the crossing signal is again activated a fixed number of seconds before the rear of the train enters the crossing. This fixed warning time remains substantially constant regardless of train direction or speed and can be adjusted to a number of values.

It is also the intent of this description to disclose a method of deriving a uniform time warning by selective manipulation of coupling impedances.

The basic equipment for the scheme is shown in FIG. 1. It includes a track transmitter **20** with a designated value of source impedance ZS connected to the rails **10** and a track receiver **21** with a desired value receives input Z_{in} coupled to the transmitter **20** through the rails **20**. As the train (represented by shunting wheels **11**) approaches the crossing, the receiver voltages E_R follows the curve shown in FIG. 2. This curve has a constantly changing slope which may be determined in this application as the difference between any two successive values of the received voltages E_R over respective values of distance for a constant measuring period. This slope increases as the train approaches the crossing. The receiver has a slope detector **31** built into it and it detects a certain value of slope or greater for activating output generator **41**. This particular slope is the predetermined value indicative of the uniform warning time. Generator **41** triggers warning signal **51** when the proper signals are received. High-speed trains are detected when the train is a considerable distance from the crossing; while slow-moving trains are not detected until they are relatively close to the crossing.

FIG. **2** shows the relation of receiver voltage E_R vs. S the distance to the crossing. It should be pointed out here that the curve of FIG. **2** has been normalized to a curve in the first quadrant and that the values A and B are absolute values to be compared as explained later in this disclosure with respect to the comparator polarities. It is necessary at this point to determine the slope by arithmetic differentiation as follows. The slope is generally defined as a change in the ordinate over the change in the abscissa value or

$$\Delta E/\Delta S \text{ where } m \text{ is the slope} \quad (1)$$

$$m=B-A/S_2-S_1 \quad (2)$$

The rate which the train crosses the crossing determines the magnitude of the difference between A and B over a set period of time. If the train moves swiftly, the difference of B and A is large with respect to the distance. On the other hand, if the speed is halved as shown further in FIG. 2, then the slope represented in equation (2) is not achieved until the vehicle reaches a distance to the crossing which is half of 2500 feet or, as shown, 1250 feet. In accordance with this explanation, it can be seen that:

$$m=\Delta E/\Delta S=\Delta E'/\Delta S' \quad (3)$$

when

$$(B-A)/(S_2-S_1)=(B'-A')/(S_2'-S_1') \quad (4)$$

If the speed of the vehicle for the left side of the equation is two times the speed of the vehicle for the right side of the equation. If a minimum slope detection is set, it is possible to determine from the curve the distance from the crossing at which the signal is actuated for each train speed.

The FIGS. **4A–4D** show curves which represent the variations in warning time for different values of receiver impedance. By correct proportioning of the transmitter source impedance and the receiver input impedance, an almost uniform warning time can be achieved for trains over a wide speed variation. For the sake of example, a uniform time of 25 seconds is shown for these curves represented by the dotted line in each figure.

FIG. **4A** shows curves representing high receiver impedance characteristics. At low track ballast R_b=5 ohms per 1000 feet, the curve approaches the uniform warning time. However, it is somewhat below the time and would not be reliable in terms of safety. A high track ballast R_b=300 ohms per 1000 feet produces a characteristic curve which deviates greatly from the uniform time.

FIG. **4B** shows the characteristics, for low receiver impedance. While the uniform warning time at low track ballast is within a useful range at high track ballast, again the curve shows a large deviation from what would be considered a uniform warning time.

FIG. **4C** shows the optimum receiver impedance for this configuration. However, as can be seen from the curve, when track ballast is high, the warning time tends again to be somewhat away from the uniform warning time. In order to alleviate this problem, the track circuit of the system is artificially loaded to reduce the effect of high track ballast on the system. This loading is represented by impedances *Za* in FIGS. **1** and **5** at a distance of approximately 2500 feet from the crossing. The curves in FIG. **4D** illustrate the relatively small deviation from the uniform time for extreme values of track ballast resistance. The correct proportioning of these impedance values assists in the shaping of the curve in FIG. **2** such that for a substantial range of values the curve varies logarithmically with respect to the distance from the crossing. At distances below 375 feet from the crossing, the logarithmic variation breaks down so that a special circuit has been incorporated into the system for detecting speeds below 15 feet per second. This circuit gives at least a 25 second warning for low speed trains within 375 feet from the crossing. However, this type of situation is or would be rare on the applications called for since warning system is essentially designed for use where relatively rapidly moving trains with varying speeds are prevalent.

FIG. **5** shows a partial block diagram of the system incorporated into the invention. Transmitter **20** with proper source impedance generates an input signal which is impressed upon the rails **10** at the highway crossing. Receiver **21** coupled to the rails at the highway crossing receives the input signal. However, if a train is on the tracks as represented by the wheels and axle **11**, then the input signal is modified to a value proportional to the distance S of the wheels **11** from the crossing HC. The modified input signal is received by bandpass filter **22** which eliminates signals other than at a carrier frequency F1. This modified signal is transformed by step-up transformer **23** and rectified by full-wave rectifier consisting of diodes **24** and **25**. The diodes **24** and **25** are reverse bias so that the polarity of the modified signal must be negative to pass. Resistor **26** and parallel connected capacitors **27** and **28** smooth out the DC rectified signal and provide a receiver signal at point A. The amplitude of the receiver signal represents the distance to the crossing.

Detector **31** is used to sample the values of the receiver signal at periodic intervals. During each interval, the signal is sampled and held for a fixed amount of time. This sample is then compared with the next succeeding sample. When the first sample exceeds the second by a certain amount as determined by comparator 42, then a signal is generated which causes the railroad crossing to be activated.

The receiver signal at point A is fed into amplifier 34 through resistor R1 and field-effect transistor (FET) switch 33. Pulse generator 32 gates the FET switch and allows the FET 33 to turn on amplifier 34 when the pulse generator is in an ON condition. During this ON time, a sample of A is taken and fed into amplifier 34 to be held on capacitor C1. Resistors R1 and R2 set the proportions for the amplification of amplifier 34. The signal A is then held in amplifier 34 for the OFF period of a pulse generator 32. At the next succeeding ON time of generator 32, the output of amplifier 34 at signal A is transmitted to B as a positive magnitude signal equal but opposed in polarity to its original value. Again, a sample is taken at point A. This sample is then compared with the value of B through the voltage divider R3 and R4 at point C. R3 and R4 are equal in value and so the value at C represents the difference between the voltages A and B.

Output generator 41 is used to detect when C is of a certain value and provides a triggering signal such that the railroad crossing 51 is activated. Comparator 42 is responsive to the signal at C and is biased by the time warning adjustment 40 to a preset value representative of the desired uniform warning time. When the signal at A becomes less than the signal at B by the value set in time adjustment 40, then comparator 42 generates an output indicative of the fact that the certain set slope of the track voltage has been exceeded. The slope may be determined in accordance with the previous definition as the difference in voltage between B and A per the OFF period of the pulse generator 32. If the frequency of the pulse generator is relatively high, the slope calculation approaches the accuracy of a direction differentiation.

In the previous discussion of the slope, relative to vehicle speed, it was shown that vehicle speed is measured only incidently in that differences in the distance are determined as a function of received voltage E_R (i.e. for each value of E_R there exists a corresponding distance S where the shunt 11 exists). If values of E_R are sampled at a fixed rate, then the speed of the vehicle is implicit in the differences between the two successive samples. This must be qualified by the assumption that the curve which E_R follows is defined. If, for example, the received voltage varied in accordance with equation of a straight line, then the actual differences of A and B could be directly correlated to the speed. However, the nature of the track circuit is not so convenient, as may be seen by the various curves of FIG. 4. If, therefore, E_R is caused to vary approximately as a logarithmic curve shown in FIG. 3, then the speed of the vehicle may be determined indirectly as a function of the differences in the received voltage E_R over the differences in distances from the shunt to the crossing over a defined interval of time. This is because the change in E_R is not a constant. In this respect, it should be noted that this agrees with equation (2) because the variation in the curve in FIG. 2 must be correlated with a specific distance S_1 and S_2 that the shunt 11 is from the crossing. In the linear equation, on the other hand, S_1 and S_2 have no net effect on the equation, because the value of E_R is directly correlated to distance of the vehicle from the crossing.

An example of a numerical approximation method of arriving at distances at which the warning must be activated is described by the following example with reference to the curves E vs. S FIG. 2. A train travelling at 100 feet per second would require 25 seconds to reach the crossing from a distance of 2500 feet. The slope of the curve R_b=5 ohms per 1000 feet at 2500 feet for a 1 second interval equals one-fourth. If the velocity value is reduced to 50 feet per second, then the slope on the same curve would be equal to one-eighth at 2500 feet. However, the slope of the curve at 1250 feet is approximately one-fourth. This means that if the slope detection is set for example at one-fourth, then the signal 51 at the crossing HC would be activated at a distance of 2500 feet from the crossing at a train speed of 100 FPS and in the vicinity of 1250 feet from the crossing at 50 FPS. For various speeds, the slope can be picked off the curve knowing what uniform warning time is desired and the measuring period. It is true that the faster the detecting rate is, the more accurate will be the detection of the slope for various speeds. However, what has been shown by way of example to illustrate the way in which the curve of FIG. 2 varies with respect to the distance to the crossing and the velocity of the vehicles approaching the crossing. For high track ballast resistance situations as illustrated by the curve R_b=300 ohms per 1000 feet in FIG. 2, the warning time is increased as shown in FIGS. 4A–4D. Low track ballast resistance provides a response yielding the shortest warning time and the system for safety has been designed with reference to low track ballast resistance values.

The polarity connection on comparator 42 makes it only sensitive to negative values of slope, i.e. values of A less than values of B as the train approaches the crossing. With this arrangement, comparator 42 starts generating an output pulse for every period of the pulse generator, a uniform time before the train enters the crossing regardless of the train speed. This output pulse is transmitted to a one-shot multivibrator 43 which turns on in response to the pulse. The one-shot produces a pulsing signal which is transformed through transformer 44 and rectified to a full-wave DC signal through diodes 45. The rectified signal energizes relay 46 opening back contact 47 which deenergizes relay 49 through closed front contact 48. The deenergization relay 49 drops back contact 50 energizing the crossing signal 51. When the train passes the highway crossing, comparator 42 sensitive only to negative values of slope will stop producing output pulses and the one-shot 43 ceases to be triggered consequently dropping relay 46. However, the crossing will not be turned off because contact 48 has at this time been deenergized by another circuit as will be explained later on. Comparator 52 is sensitive to positive values of slope as seen from its polarity connections.

As soon as the train passes the crossing HC, the values of A and B change and B becomes less positive than A indicating a positive slope. This positive slope is detected by comparator 52 sensitive only to positive slope because of biasing resistor 58 which generates a signal to one-shot multivibrator 53 which produces a pulsed output which is transformed by transformer 54, rectified by full-wave bridge including diodes 55 for energizing relay 56 picking up contact 57 and energizing relay 49, which picks up contact 50 and deenergizes the signal.

As was previously noted, for trains moving below a specified minimum speed in the order of 15 miles per hour, low-speed warning time adjustment 61 is provided. Adjustment 61 is arranged to deenergize relay 65 when the train is within 375 feet of the crossing. This distance is used for convenience and may vary between 300 and 400 feet. This is accomplished by tapping the secondary of the transformer 23 which provides a voltage which is rectified by the full-wave bridge including diodes 63. The signal produced at the output of the bridge is conducted to relay 65 which remains energized. Resistor 64 is used to adjust for a minimum current in the relay 65. As the train approaches the crossing, the signal produced at the transformer 23 is constantly decreasing and the resistor 64 is adjusted to drop relay 65 when the signal produced at the secondary of the transformer is proportional to a distance of 375 feet from the crossing. This assures the trains travelling below a certain speed in the order of 15 miles per hour will be detected in order to produce a signal at the crossing of at least the uniform warning time. However, since relay 65 remains deenergized even when the train is within 375 feet of the crossing in either direction, the comparator network incorporating comparator 52 which detects positive slopes for trains moving away from the crossing, one-shot 53, transformer 54, rectifier 55 and relay 56 is used so that when the train passes the crossing HC, the signal will be immediately extinguished. The use of comparator 42, comparator 52, and low-speed warning time adjustment 61 provides a system which keeps delays to highway traffic to a minimum.

In this connection, however, it should be noted that a train stopping before the crossing within 375 feet of the crossing will cause the system to maintain the crossing signal **51** on. Similarly if the rear of the train passes the crossing and the last car is within 375 feet of the crossing and stops the signal **51** will remain energized. Any movement of the train away from the crossing after the last car passes the crossing HC, will provide sufficient signals to the system for maintaining relay **56** energized and even a very slowly moving train which has passed the crossing will not cause a signal actuation.

With reference to FIG. **2**, a method of achieving a uniform warning time will be explained with respect to the curve representing the receiver voltage at the output of the receiver **21**. This voltage varies substantially logarithmically over a range from 4000 feet to above 375 feet from the crossing. This logarithmic variation provides a characteristic which aids in the development of a simple uniform warning time system.

A mathematical derivation of the approximate expression used in this method is shown below.

From FIG. **2**, the curve E (receiver voltage) Vs. S (distance from the crossing)

The rate of change E with respect to time

$$\frac{dE}{dt}=\frac{dE}{ds}\cdot\frac{ds}{dt} \quad (5)$$

$$t=s/v \quad (6)$$

and

$$v=\frac{ds}{dt} \quad (7)$$

substituting

$$\frac{dE}{dt}=V\frac{dE}{dS} \quad (8)$$

$$t=\frac{S\dfrac{dE}{dS}}{\dfrac{dE}{dt}} \quad (9)$$

if t is to be uniform then:

$$t=\frac{K}{\dfrac{dE}{dt}} \quad (10)$$

$$K=S\frac{dE}{dS} \quad (11)$$

$$dE=Kds/S \quad (12)$$

integrating

$$E=K\ ln\ (S/S_o \quad (13)$$

The formula (13) provides an equation which if plotted would yield a curve which varies logarithmically. The variation provides a clue as to what would be a useful measuring device in uniform time-warning devices. The curves in FIG. **2** do not vary logarithmically over the complete range of values of distance to the crossing but for a sufficiently useful interval it does. The upper curve is arrived at when the track ballast resistance R_b is high in the order of 300 ohms per 1000 feet for example on hot dry days. The lower curve exists when the track ballast resistance R_b is in the order of 5 ohms per 1000 feet as may exist after a rain storm.

The curve in FIG. **3** is a true logarithmic curve becoming zero on the ordinate when the abscissa is S_0, i.e.

$Ke\ s/s_o=E$ where (14)

K is a constant

Let $K=1$ then

$E=ln\ (S/S_o$ and (15)

Therefore when $(S/S_o)=1$; $E=0$

However the curves of FIG. **2** approximate this condition between S=375 and S=4000 feet is sufficient for the purposes of the application. The variation of the track voltage E vs. S the distance S to the crossing was adjusted to approximately follow the variation according to equation (13) by manipulating the carrier frequency, input and output impedance of the receiver and transmitter respectively and the track-loading impedances. By mathematical calculation and selective empirical adjustment, the following are a range of values indicative of the absolute value of impedances which proved useful in arriving at the desired curve of FIG. **2**.

S_c=200–500 Hz.

Receiver input impedance = 2–10 ohms

Transmitter output impedance = 1–4 ohms

Track-loading impedance = 1–5 ohms

The above impedances are represented as absolute values of complex impedances as determined for the range of frequencies and variations in the track circuit impedance as a function of distance to go.

The use of the amplifier **34** and its associated circuitry for deriving the uniform warning time provides a system which is simple in its concept and efficient in its operation. The system utilizes curve-shaping techniques to provide a signal variation which is directly proportional to the uniform warning time such that complicated circuitry is not necessary for deriving the velocity function of the received voltage. Instead of differentiating values indicative of the distance to the crossing to obtain a velocity function and then solving for the uniform warning time, the system uses an approximate arithmetic method arriving at substantially the same result with a simple and efficient design. One of the key factors in the operation of the system, however, is the matching impedances to optimum values of the input and outputs of the transmitter and receiver respectively. It is to be noted in this connection that the matching of impedances mentioned above is not necessarily the matching of impedances in the conventional sense whereby maximum power is transmitted by the exact matching of input and output impedances, but is a matching to cause the received voltage characteristic to follow the approximate logarithmic curve shown in FIG. **2**. This is why the impedance listing above shows that the receiver, transmitter and track-loading values are substantially different from each other. It is called the matching of impedances in this disclosure because it achieves the purpose of shaping the response curve of E_R to the desired characteristic. However, in literal electrical engineering terminology, it is miss-match of impedances and not a conventional means for transferring a signal. In addition, the choice of frequency is also important for this system. For frequencies higher than an order of 500 Hz., a standing wave pattern is set up because a set of rails reveal characteristics similar to that of transmission line for the distance involved in track circuits of this invention. If a higher frequency is used, the curve would not vary logarithmically and the results desired would therefore not occur. For frequencies higher than 500 Hz. the voltage-distance curve, at low track ballast conditions rises, becomes flat and finally reverses and goes down again as the shunt moves away from the feed point at distances less than the minimum required warning distance of 2500–3000 feet. With this type of voltage-distance curve response, the described uniform time warning system would generate erroneously short warning times for fast trains.

Having described an apparatus and method for deriving a uniform time warning it is to be understood that various modifications and alterations may be made to the specific embodiment shown without departing from the spirit or scope of the invention.

What I claim is:

1. An improved control system for a railroad crossing warning providing a uniform warning time having a transmitter for impressing an alternating current input signal on the rails in the proximity of the crossing, said signal modified by vehicle movement, along the rails and a receiver likewise coupled to the rails proximate to the crossing responsive to the magnitude of said modified input signal for initiating the warning wherein the improvement for providing the uniform warning time comprises: means for sampling said modified signal detection means included in the receiver responsive to the difference between any two successive samples of said modified signal for producing a triggering signal for initiating the warning when said differences achieve the preset value; and

impedance compensating means coupled to the output and input of the transmitter and receiver respectively for influencing the variation of said modified signal such that said modified signal varies substantially at an exponential rate whereby for various vehicle speeds the modified signal achieves the preset rate and the warning is activated at a uniform time prior to the vehicle's arrival at the crossing.

2. The control system of claim 1 wherein said impedance compensating means comprises:

an output impedance coupled to the transmitter, and

an input impedance coupled to the receiver, said output and input impedances ranging in magnitude from 1 to 4 ohms and 2 to 10 ohms respectively.

3. The control system of claim 2 wherein said impedance compensating means further includes an impedance in shunt across the rails disposed on opposite sides of the crossing at the extreme range of the system for stabilizing the impedance of the rails under various climatic conditions.

4. An improved control system for activating a railroad crossing signal and establishing a uniform warning time as a function of vehicle speed comprising:

a transmitter coupled to the rails proximate to the crossing for generating an input signal, the amplitude of the input signal modified by shunting of the rails by vehicle wheels;

a receiver coupled to the rails likewise proximate to the crossing responsive to the modified signal for producing a receiver signal representative of said modified signal; wherein the improvement comprises:

a detector responsive to the receiver signal for sampling the amplitude of the receiver signal at a predetermined periodic rate; and

means responsive to the detector producing a first output signal for activating the crossing signal, when the difference between any successive pair of periodic samples of one polarity is greater than a predetermined value indicative of the uniform warning time,

the amplitude of the receiver signal varying approximately as an exponential function of the distance of the vehicle to the crossing.

5. The improved control system of claim 4 wherein said exponential variation follows the approximate formula:

$$E=K\ln(S/S_o)$$

where E is the received signal

K is a constant

S is the measured distance to the crossing

S_o is the value of the premeasured distance to the crossing

$\ln(S/S_o$ is a natural logarithmic expression representing the exponential variation of the receiver signal.

6. The improved control system of claim 5 wherein the transmitter comprises:

a signal generator for producing the input signal at a predetermined frequency, the input signal represented by a potential across the rails; and

impedance compensating means coupled the signal generator to the receiver through the rails for influencing the characteristic of said receiver signal such that the receiver signal varies exponentially.

7. The improved control system of claim 5 wherein the receiver comprises:

a filter responsive to said modified signal for eliminating modified signals of other than predetermined frequency; and

a rectifier responsive to the filtered modified signal for converting the filtered modified signal into the receiver signal.

8. The improved control system of claim 5 wherein the detector comprises:

a pulse generator for producing the period of the detector;

a switching means responsive to the pulse generator for gating the detector;

an amplifier periodically gated by the switching means for sampling the receiver signal; and

delay means controlled by the switching means for controlling the output of the amplifier, the delay means being effective to hold the sampled signal in the amplifier until the next succeeding gate of the switching means.

9. The improved control system of claim 8 wherein the means responsive to the detector for producing the output signal includes:

a comparator responsive to the output of the detector for producing a triggering signal, when the difference between the sampled signal and held signal exceeds the predetermined value;

an output switching circuit having a conductance state responsive to the triggering signal; and

the output signal is produced in response to the conductance state of the output switching circuit, the output signal energizing the warning device when the switching circuit is in said conductance state.

10. The improved control system of claim 4 including means responsive to the detector producing a second output signal for deactivating the crossing signal when a difference between any successive pair of periodic signals exists at an opposite polarity.

11. The improved control system of claim 4 including means responsive to the receiver for activating the crossing signal when a railroad vehicle is within a minimum predetermined distance from the crossing.

12. An improved method for predicting when a railroad vehicle will reach a railroad crossing and energizing a warning device at a uniform time before such occurrence involving the procedure of:

imposing an input signal on the rails having a peculiar characteristic;

attenuating the signal by vehicle movement along the rails; wherein the improvement for producing a uniform warning time comprises the steps of;

detecting the slope characteristic of the attenuated signal; comprising the steps of:

measuring successive values of magnitude of the attenuated signal at a periodic rate;

storing the first of successive values of the attenuated signal measured; and

summing the stored signal with the next successive measured signal over the time interval, said summation indicative of the slope characteristic of the attenuated signal over the period encountered;

generating a first output signal for energizing the warning when the slope characteristic of the attenuated signal is one polarity and reaches the predetermined value; and

selectively adjusting impedance coupling of the input signal and the detected attenuated signal such that the magnitude of the attenuated signal varies logarithmically relative to the input signal, whereby for various vehicle speeds the attenuated signal reaches the predetermined value at a time substantially at a uniform time before the vehicle reaches the crossing.

13. The improved warning system of claim 12 wherein detecting the slope of the attenuated signal comprises the steps of:

a. measuring successive values of magnitude of the attenuated signal at a periodic rate;

b. storing the first of successive values of the attenuated signal measured; and

c. summing the stored signal with the next successive measured signal over the time interval;

said summation indicative of the slope characteristic of said attenuated signal over the period encountered.

14. The improved warning system of claim 13 wherein the summation of the stored signal and next successive measured signal further comprises the steps of:

inverting the polarity stored signal so that the summation yields a difference between said stored signal and next successive measured signal.

15. The improved method of claim **12** further comprising:

generating a second output signal for deenergizing the warning when the slope characteristic of the attenuated signal achieves the opposite polarity, when said vehicle is past the crossing.

16. The improved method of claim **12** further comprising:

generating a third output signal for activating the signal when the attenuation of the signal achieves a minimum threshold indicative of vehicle presence at a minimum predetermined distance to the crossing.