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[54] LONG LENGTH TRACK CIRCUIT

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[58] **Field of Search** .....246/40, 34, 34 CT, 8, 38; 325/5, 13, 52, 1

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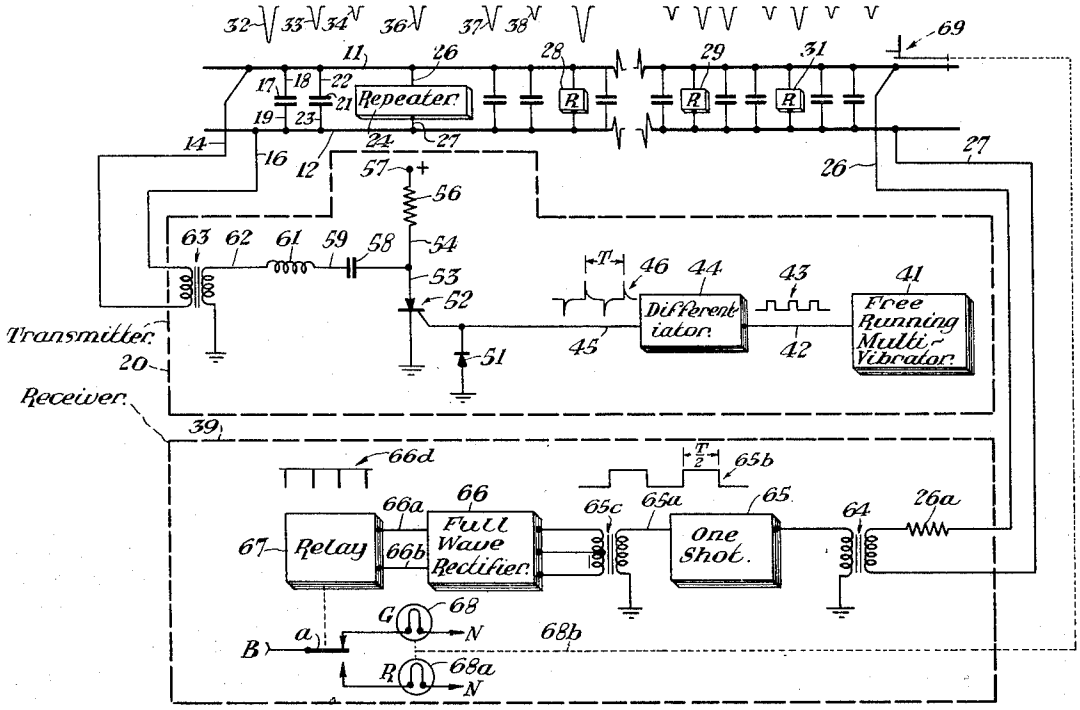
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[57] **ABSTRACT**

This invention relates to a long length track circuit for electrically continuous tracks having a signal-transmitting end and a signal-receiving end which includes interposed therebetween at least one signal repeater coupled across the rails without interrupting the electrical continuity of the rails of the track circuit to provide a repeated signal to the receiving end. The circuit further includes a plurality of capacitors coupled across the rails to thereby decrease signal attenuation and thereby improve overall track circuit performance.

6 Claims, 2 Drawing Figures



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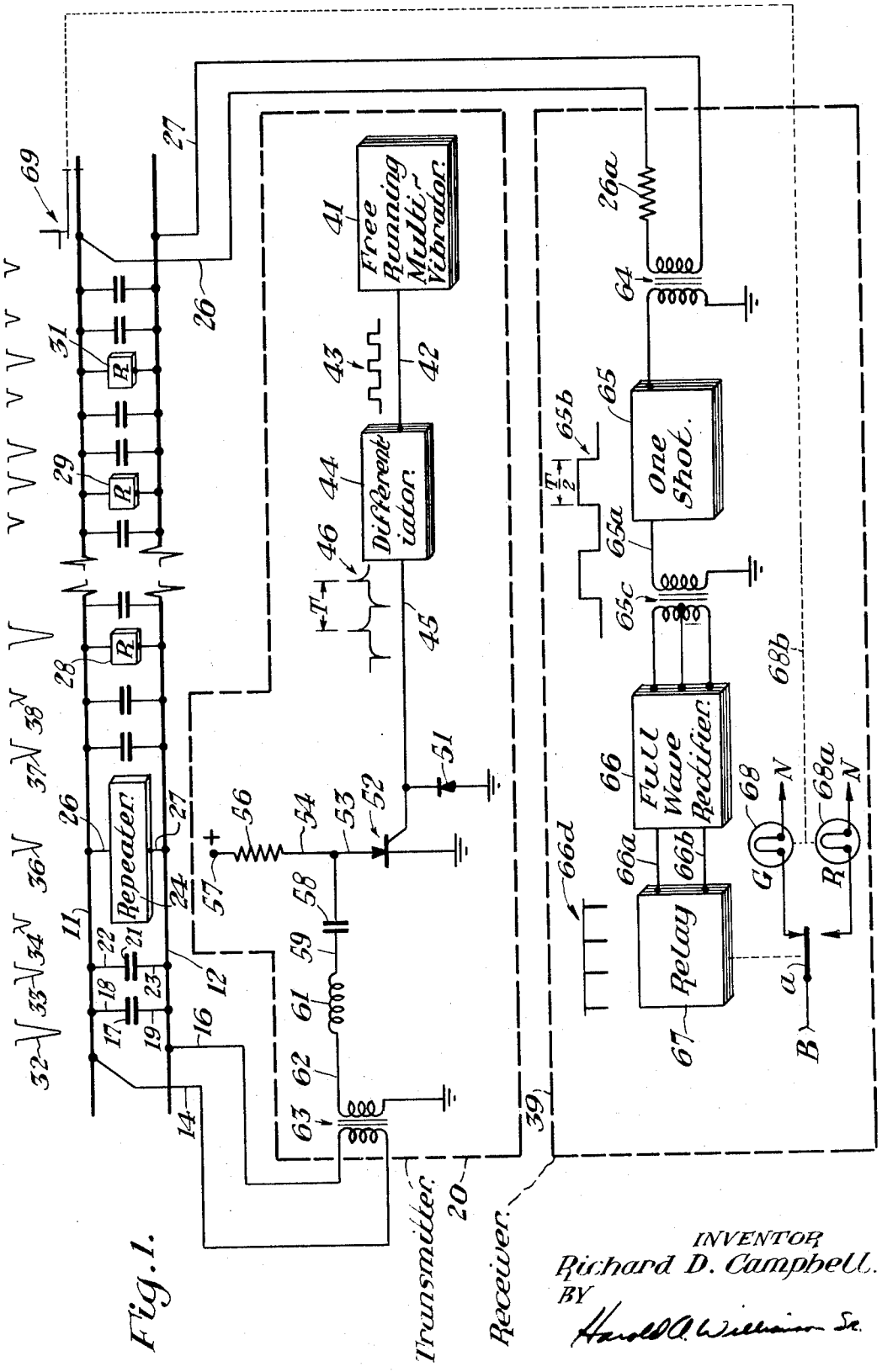


Fig. 1.

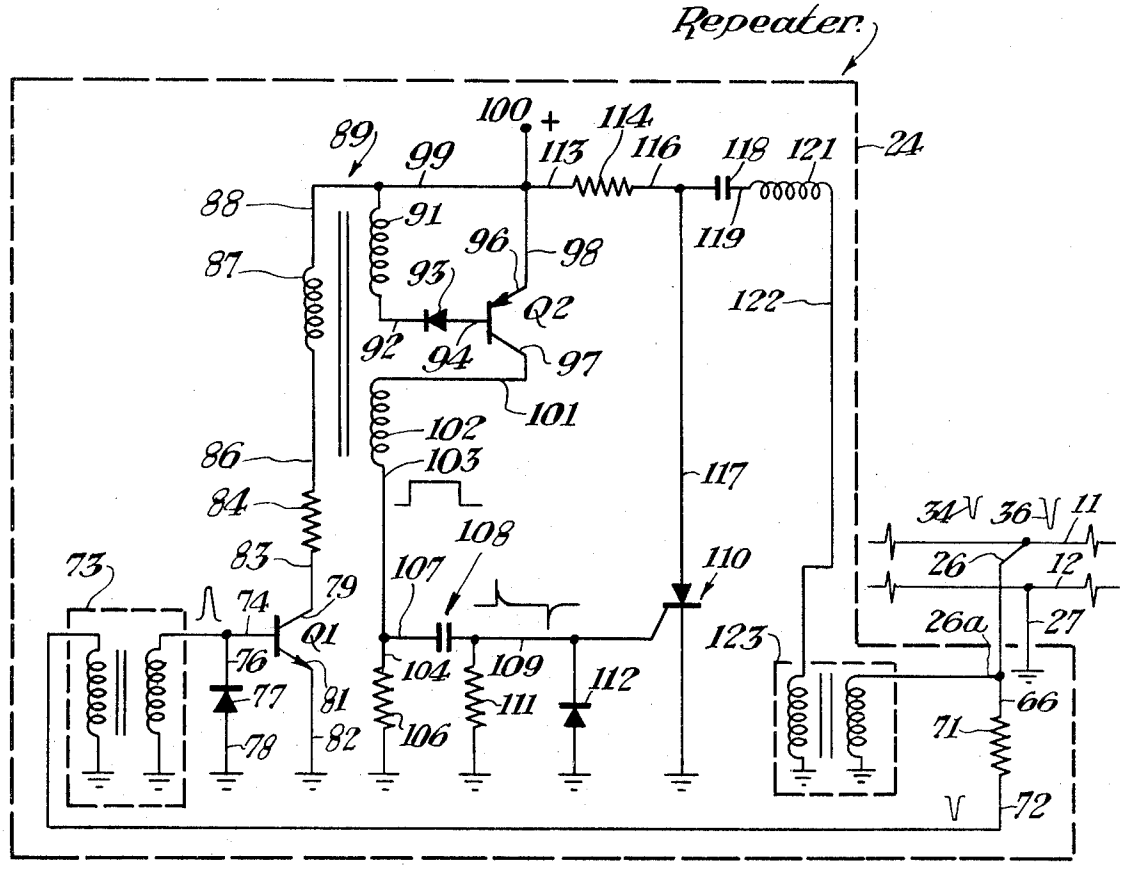


Fig. 2.

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LONG LENGTH TRACK CIRCUIT

This invention relates to a track circuit system.

More specifically this invention relates to a track circuit system for use with electrically continuous rails, which system includes a signal transmitter and a receiver that are spaced apart and respectively electrically coupled to the rails. Situated at a point intermediate the transmitter and receiver is at least one signal repeater that is electrically coupled to the electrically continuous rails. Whenever a signal from the transmitter is received by the repeater an amplified signal is generated by the repeater and transmitted through the rails to the receiver.

The railroads of today are experiencing a renaissance marked by exciting growth in main line operation while signaling costs threaten to choke off the use of feeder spurs that extend off the main line and are used only a few times daily, or in many instances only a few times weekly.

For these short runs or spurs, which may be from a few miles in length to 20 miles or more, the very thought of establishing effective continuous signaling is abhorrent to the many minds of those in railroading management that view these spurs with increasing disdain because of the costs involved in maintaining effective communication of train passage over these spurs. One way to handle the problem of determining whether a section of track may be available for entry is to string line wires along the way and proceed with a call to the other end to ascertain track availability. This approach quite obviously requires someone at the other end of the line to respond to inquiries. How convenient it would be if only the rails were available to establish a track circuit as long as 20 miles. To this almost impossible dream the invention to be described provides an answer with a technologically fresh approach heretofore never tried. This fresh approach is exactly what has been accomplished by the invention to be described more fully hereafter.

It is therefore an object of this invention to provide a track circuit system that may be of extraordinary length where electrically continuous rail can be created, by the utilization of a signal-repeating arrangement which allows for communication over any desired length of such track.

A prime object of this invention is the creation of a track circuit that can be applied to any preexisting track that can be made electrically continuous by the inclusion of a signal repeater or repeaters which do not require any more than a mere connection to the rails, thereby doing away with the need to physically interrupt the electrical continuity of the rails.

Another object of this invention is to provide a track circuit system of great length which may have its total electrical integrity checked from one end thereof.

Still another object of this invention is the provision of a track circuit that may continue to function in a flawless unimpaired fashion even though many of the individual components involved may fail.

A further object of this invention resides in the enhancement of signal transmission between repeaters by the inclusion of capacitors across the rails where environmental conditions dictate further track circuit integrity.

Yet another object of this invention is the provision of a track circuit system of great length which has an extremely low power requirement such that with conventional storage batteries virtually continuous operation may be maintained over great periods of time, and with even less frequent use, even longer periods of time.

In the attainment of this invention a track circuit system in this preferred embodiment which requires the presence of electrically continuous rails, or rails which have been made electrically continuous by electrical bond wires around preexistent jointed track, includes a pulse signal generating transmitter electrically coupled to the rails at a first point as well as a pulse signal receiver electrically coupled to the rails at a second point. There are in addition a plurality of pulse repeaters electrically coupled across the rails at points which are

intermediate the first and second point. Each of the pulse repeaters possesses an ability to be nonresponsive for a period after a pulse signal has been received and a repeated pulse signal has been transmitted by the repeater. This nonresponsive period provides each of the repeaters with an immunity from responding to repeated signal pulses from other repeaters after an initial signal pulse has been received and a repeated signal transmitted.

In any of the embodiments contemplated there may be provided a plurality of capacitors electrically coupled across the rails intermediate the pulse signal transmitter, and some or all of the repeaters and the receiver. These capacitors will provide improved signal transmission through the rails by reducing signal attenuation along the rails.

Other objects and advantages of the present invention will become apparent from the ensuing description of illustrative embodiments thereof, in the course of which reference is had to the accompanying drawings in which:

FIG. 1 is a circuit diagram of a system depicting a preferred embodiment of the invention where the repeaters employed are set forth in block diagram form.

FIG. 2 is a repeater circuit suitable for use in the circuit diagram of FIG. 1.

A description of the above embodiment will follow and then the novel features of the invention will be presented in the appended claims.

Reference is now made to FIG. 1 which illustrates in circuit diagram a preferred embodiment of the invention to be described. In the basic embodiment all that would need to be present would be a transmitter **20** coupled across the rails **11** and **12** via leads **14** and **16**. Across the rails are shown a plurality of capacitors between the transmitter **20** and a repeater unit **24**, which repeater will repeat a signal delivered from the transmitter to the repeater, and from the repeater an amplified signal will be transmitted along the rails toward the right where it will be repeated by an additional repeater **28** which is also coupled across the rails. Depicted at the far right of FIG. **1** is a receiver **39** which is coupled across the rails **11** and **12** via leads **26** and **27**, and receives a repeated signal initially generated by the transmitter **20**. There are shown in this FIG. **1** a number of capacitors coupled across the rails between the transmitter and each of the repeaters. The function of these capacitors will be explained more fully hereafter, as well as the details of the repeaters themselves.

Without going into the details of the transmitter **20** and receiver **39** at this point, suffice it to say that a pulse of the type shown above the rail **11**, that is pulse **32**, will be generated by the transmitter **20** and will be impressed on the rails **11** and **12** over the leads **14** and **16** from the transmitter **20**. These pulses of the type **32** will pass down along the rails, and, as can be seen from the showing immediately above the rail **11**, the pulse **32** becomes attenuated as it passes along the rail and this factor of attenuation is conveyed by the pulses **33** and **34** which are shown to be decreasing in size due to the attenuation caused by transmission through the rails.

Coupled across the rails **11** and **12** are a plurality of capacitors **17** and **21** connected respectively by leads **18**, **19** and **22**, **23** to the rails **11** and **12**. These capacitors improve the transmission of the pulses along the rails.

The incorporation of additional capacitance between the rails results in lowering the attenuation of a signal impressed on the rails of the track circuit. This improved attenuation factor of the track circuit logically flows when the inherent track circuit parameters of resistance, inductance, leakage conductance and capacitance between the rails have all been considered. It has been discovered that the placement of a plurality of capacitors between the rails to thereby vary only one of the above parameters results in a measurable advantage with reference to the frequency response of a track circuit of a given length without capacitor coupling, as well as decreasing the attenuation of signals impressed on the rails. It has been found that when the capacitance between the rails is increased such that the ratio of the leakage conductance to the

capacitance approaches numerically the ratio of the resistance of the rails to the inductance of the rails, the resulting track circuit has improved characteristics with reference to both attenuation and frequency range. These improved characteristics may be needed when the track circuit of the instant invention is employed in a territory where terrain and accompanying ballast characteristics upon which the track is laid vary with changes in weather, thereby creating zones where an increased number of capacitors are needed within a given zone to afford improved signal propagation through the zone.

It suffices to say that the capacitors **17** and **21** connected across the rail **11** by leads **18**, **19** and **22**, **23** have been selected to provide for the maximum reduction in signal attenuation should their incorporation be deemed warranted. One such example of their need can be readily recognized in areas where excess moisture accumulates in the ballast in spur lines, especially those which receive only minimal maintenance care. The remaining capacitors depicted, which are not numbered, may or may not be included but have been included to illustrate their maximum utilization in the preferred embodiment.

As noted earlier, there is coupled across the rails a repeater **24** connected to the rails **11** and **12** by leads **26** and **27**. It will be seen as one passes from the left-hand side of this figure toward the right that there are a plurality of repeaters **24**, **28**, **29**, and **31**, all electrically coupled across the rails and each positioned such that it will receive an attenuated pulse, such as the pulse **34**, and each repeater will in turn amplify and retransmit a repeated pulse **36** to the rails **11** and **12**, such as that shown above and after repeater **24**. The repeated pulse **36** will in turn experience attenuation and the pulses **37** and **38** are illustrative of this decreasing amplitude of the pulse due to attenuation.

For the practice of this invention the selection of narrow pulses has been made in order that these narrow pulses permit the filtering out of low-frequency noise which is believed to predominate in track circuits in general. In determining the positioning of the repeaters, as well as the function that they must perform, it should be recognized that the propagation time of pulses along a hypothetically loaded track is approximately 0.14 millisecond per thousand feet where a maximum attenuation of 10,000 feet of 0.8 millisecond pulse is about 22 db. and the minimum attenuation, depending upon ballast conditions, is about 3.7 db. It should be noted at this point that the loaded track referred to above has been selected only to set forth an environment in which the invention can be described and that the Figures selected are by way of example only. It should be recognized that all the track environments will produce different propagation times and in the dissertation that follows this should be kept in mind. Accordingly, if repeaters are connected every 10,000 feet in wet weather, the output of each repeater will reach maximum attenuation of 22 db. before it reaches the input of the next repeater. In this case, if one is referring to repeater **24**, then the next repeater to receive a repeated pulse would be repeater **28** followed by repeaters **29**, **30** and **31**. If one were to allow a margin of 3 db. for each repeater, the repeater should be able to be triggered by an input signal 25 db. below its own output signal.

In the system being described here, each repeater must be absolutely dead, that is, unable to react, from an input pulse for some interval after it has fired. This is because once the repeater, for example repeater **24**, has repeated a pulse and delivered it into the rails **11** and **12**, this repeated pulse will go in both directions along the rails **11** and **12**, and when the repeater **28** repeats a received pulse, this repeated pulse will pass both to the right and left along the electrically continuous rails **11** and **12**, and should the repeater **24** not be dead, that is, unable to respond to a repeated signal from repeater **28**, then the repeater **24** would produce a signal and the obvious confusion of signals that would appear throughout the length of the track circuit becomes a very large problem. Accordingly, one must calculate the time interval these repeaters must be dead. In calculating this interval of dead time one must look at the problem in dry weather conditions where typically the attenuation is 3.7 db. for 10,000 feet of rail. Therefore, in 80,000 feet, approximately 15 miles, a signal would suffer a minimum attenuation of 30 db. This would be 5 db. below the specified input noted above with reference to the sensitivity selected at each receiver. And so a repeater could not directly trigger another repeater 80,000 feet away but it could trigger intervening repeaters as has been noted earlier.

In the preferred embodiment, by way of example, repeaters are located every 10,000 feet. If a pulse is transmitted at time T=0 and this pulse comes from the transmitter 20, the first repeater **24** will receive a somewhat attenuated pulse at T=1.4 milliseconds, and then repeater **24** will fire. In a similar fashion, at T=2.8 milliseconds the first repeater pulse will arrive back at the transmitter and simultaneously appear at the second repeater **28** and trigger the second repeater **28**. This process goes on and on so that a new pulse is introduced into the rails at a 2.8 millisecond interval after the first repeater **24** is triggered. As noted, under dry conditions the first repeater pulse **32** will travel 80,000 feet down the track in 11.2 milliseconds, thereby triggering the ninth repeater. This ninth repeater pulse will travel 80,000 feet back to the No. **1** repeater in the same 11.2 milliseconds.

In view of the computations of the preceding paragraph and attenuation parameters noted heretofore, this signal will always be too weak to retrigger the first repeater **24**. Each repeater must therefor be dead for approximately 22.4 milliseconds after it is fired to insure that it is not retriggered by a subsequent pulse. In practice there is allowed a substantial margin since the time is set at 30 milliseconds.

This repeater system is especially unique in that it is easy to trouble-shoot and maintain. In dry weather one would merely connect at the transmitter end of the track circuit an oscilloscope. One would then see the transmitter pulse which, in this instance would be approximate 10 volts, followed by the first repeater pulse which would be about 6.7 volts, followed by the second, etc. This is a string of pulses each one two-thirds the size of its predecessor. If one repeater has failed or has a dead battery, then the pulse of the collection of pulses normally present from a repeater that has failed will be missing. One thus can do the maintaining of this track circuit system during dry weather based on oscilloscope measurements at the ends of the track circuit. Of course, were one to do the measuring from the receiver end of the track circuit, a pulse would have to be introduced into the rails at that end in a manner not illustrated but with any electronic pulse device that could provide the required pulse characteristic referred to earlier. It is also worth noting once again that some of the repeaters may fail without doing any harm except in very wet weather where attenuation might be so great as to prevent the leap frogging of the repeaters that have failed. It is important to note that the repeaters, which will be described in detail hereafter, are of such a design that they do not load down the rails should one of them fail, for if any one of the repeaters fails, it neither abstracts from or adds energy back onto the rails. Accordingly, if the ballast resistance is not too low, this signal will leapfrog a dead repeater and trigger the next repeater down the line.

It is this unique capacity which allows parts of the system to fail while simultaneously allowing the system to continue operating umimpaired that sets this invention in a category of inventions of the highest order.

The repeater must meet certain basic requirements consistent with the requirements that are demanded by the Association of American Railroads. Accordingly, the repeater must be fail-safe in addition to providing the above-noted 30 millisecond dead time. The fail-safeness requires that the repeater must not fire spontaneously or, on the other hand, the internal gain of the repeater must not increase so that weaker signals might trigger the repeater, and finally, the dead time must never get shorter or decrease to zero. In concluding, the output pulse of the repeater must never increase in amplitude.

With these basic understandings of the positioning of the repeaters along the track, a study may now be made of one embodiment of this invention which includes a transmitter and a receiver. Where a transmitter along is present, as depicted in the preferred embodiment, then a track circuit of a very great length might be present and all that would be required of the transmitter is the placing of a pulse into the track which would be repeated down the length of the track circuit to a receiver many miles away.

The transmitter **20** of FIG. **1** may take the form depicted therein but the invention is not to be construed as being limited to the pulse transmitter shown. The transmitter **20** includes a free running multivibrator **41** of conventional design powered by a source not shown. The multivibrator **41** produces one output on lead **42** of the type depicted by square wave pulse form **43** depicted immediately above lead **42**. This square wave pulse form **43** is delivered to differentiator **44** which is of conventional design. An output appears on the lead **45** of the type shown by curve waveform **46** and this waveform signal is delivered to silicon-controlled rectifier (SCR) **52**. The leading edges of the square wave pulse form **43** are differentiated to produce the positive going pulse portions of waveform **46** which are necessary to trigger the silicon controlled rectifier **52** into conduction. A diode **51** is electrically connected to the gate lead **45** and provides protection to the silicon-controlled rectifier **52**. The diode **51** quite obviously also assures an electrical path to ground when the trailing edge of the square wave pulse from the free running multivibrator **41** is differentiated to produce a negative going spike. The silicon-controlled rectifier **52** is electrically connected in a circuit between a positive battery terminal **57** and ground via resistor **56**, leads **54**, **53**, silicon-controlled rectifier **52**, and finally ground.

As noted, when the spike pulse due to the differentiation of the leading edge of the square wave output from multivibrator **41** appears on gate lead **45**, this triggers silicon-controlled rectifier **52** into conduction. The silicon-controlled rectifier **52** once conducting will remain conducting until the voltage bias between anode and cathode of the silicon-controlled rectifier **52** falls below zero at which time the silicon-controlled rectifier **52** will cease to conduct. In addition to the circuit between the positive battery source **57** and ground there is a circuit which includes resistor **56**, lead **54**, capacitor **58**, lead **59**, inductor **61**, lead **62**, a primary winding of transformer **62**, to ground.

At the instant the silicon-controlled rectifier **52** starts to conduct there will be present on capacitor **58** a charge due to the battery potential on terminal **57** electrically connected thereto by resistance **56** and lead **54**. The capacitor will dump its charge through the silicon-controlled rectifier **52** to ground and in so doing, because of the electrical connection of the capacitor **58** by lead **59**, inductor **61**, lead **62** to transformer **63**, will induce in its secondary winding of the transformer **63** an output pulse which approximates a half sine wave which will be passed by leads **14** and **16** to rail **11** where it will appear as a transmitted pulse **32**. The transmitted pulse **32** will, as described earlier, be delivered to repeater **24** where the repeater **24** will respond and deliver an amplified pulse **36** to the rails **11** and **12**. Each of the repeaters **28**, **29** and **31** will perform in a similar fashion until a pulse is delivered to the receiver **39** via lead **26**, resistor **26***a*, and lead **27**, which leads are connected to the input winding of receiver transformer **64**. The presence of a pulse in the input winding of receiver transformer **64**. The presence of a pulse in the input winding of transformer **64** will induce a pulse in the output winding of the transformer **64** which is electrically connected to a one-shot multivibrator **65**. This induced pulse will fire the one-shot multivibrator **65** which is of conventional design, and thereby produce an output on lead **65***a* of the waveform **65***b* shown above the lead **65***a*. In a wholly conventional manner the output from the one-shot multivibrator **65** is inductively coupled to a conventional full-wave rectifier **66** via transformer **65***c*. The output from the full-wave rectifier **66** shown by waveform **66***d* will be delivered to a conventional DC relay **67** via leads **66***a* and **66***b*. The selection of the time duration for the appearance of the positive going portion of the waveform **65***b* should be selected to be approximately one-half the time period T shown between positive going pulses of waveform **46** noted with reference earlier to the transmitter **20**. The presence of a DC signal of the type shown by waveform **66***d* is sufficient to maintain the relay **67** in its energized condition. This energized condition in turn maintains the front contact *a* of relay **67** closed, thereby allowing completion of a circuit from battery terminal B over front contact *a* of relay **67** to a green signal **68** and battery terminal N. Accordingly, the green signal is indicative of the fact that the track circuit of the invention is unoccupied and that transmitter **20** is functioning properly.

In the event that a train should enter the track section at the point where the leads **14** and **16** of transmitter **20** are connected to the rails, the presence of the wheels and related axles would provide an electrical path across the rails **11** and **12**, thereby shunting the track circuit and preventing the passage of a pulse from the transmitter **20** to any of the repeaters **24**, **28**, **29** and **31**. As soon as the repeater pulses fail to arrive at the receiver of the track circuit, the one-shot multivibrator would cease its pulse wave output **65***b* and the full-wave rectifier **66** would cease its operation and the relay **67** would be deenergized. The deenergization of relay **67** would cause the completion of a circuit from battery terminal B over the back contact *a* of the relay **67**, red signal **68** *a* to battery terminal N. It is obvious, therefore, that a train approaching the signal **69**, which signal is shown connected by dotted line **68***b* to the signal lights **68***a*, **68***b*, would see a red or stop indication. The same red or stop signal would appear in the event of a broken rail, thereby affording fail-safe operation from this viewpoint.

Reference is now made to FIG. **2** wherein there is illustrated a circuit diagram of a pulse repeater of the type referred to in FIG. **1**. It should be noted that the repeater to be described is but one example of a repeater possessing the necessary characteristics set forth earlier. The repeater to be described will have a dead time or time during which no negative going pulse may trigger the repeater. The duration of the dead time and how it is accomplished will now be set forth. Since all the repeaters of FIG. **1** are identical, only the first pulse repeater **24** will be described. As can be seen in the right-hand portion of FIG. **2**, the repeater **24** shown in dotted outline is electrically connected across the rails **11** and **12** by leads **26** and **27**. A negative going attenuated pulse **34**, described earlier in conjunction with the description of FIG. **1**, appears on lead **26** from rail **11** and enters the pulse repeater **24**. The negative going pulse **34** travels along lead **66** through a current limiting resistor **71**. The pulse **34** continues along lead **72** until it enters a step-up transformer **73** shown in dotted outline where it undergoes a 180° inversion and appears on base lead **74** as a positive going pulse as is shown immediately above lead **74**. Connected to base lead **74** is a diode **77** electrically connected by lead **76** to lead **74** and is ground by lead **78**. This diode provides protection to the transistor Q1 by affording an electrical path to ground in the event there are excessive pulses of reverse polarity voltage or voltage surges due to external sources which may induce in the rails **11**, **12** undesirable transients.

The transistor Q1 is connected to a positive battery voltage source **100** and to ground. The collector **79** of the transistor Q1 is electrically connected to positive battery source **100** via lead **83**, resistor **84**, lead **86**, primary winding **87** of transformer **89**, and leads **88** and **99**. The emitter **81** of transistor Q1 is connected to ground by lead **82**. Before transistor Q1 conducts the voltage at the collector **79** is at a positive level. The appearance of the positive pulse on base lead **74** causes the transistor Q1 to conduct and the output across transistor Q1 will follow the pulse on the base lead **74**, thereby inducing in the primary winding **87** of the transformer **89** a negative going pulse which will in turn induce in winding **91** of the

transformer 89 a negative going pulse which will appear on lead 92. Accordingly, signals are standardized by transistor Q1 which delivers a current pulse of constant size for all inputs above threshold. The transistor Q2 has its emitter 96 electrically connected to the positive battery source 100 via lead 98. The collector 97 of transistor Q2 is electrically connected to ground via lead 101, transformer winding 102, lead 103, lead 104, and resistor 106. As was noted earlier, there is a negative going pulse present on lead 92, which pulse will pass through the diode 93 to base lead 94 of the transistor Q2. This negative going pulse will trigger this transistor Q2 into conduction. As soon as transistor Q2 begins to conduct, an increasing voltage will appear in transformer winding 102 which will, through regenerative feedback, cause the negative going condition on lead 92 and base lead 94 to continue in a negative direction, thereby keeping the transistor Q2 conducting. The transistor Q2 and transformer 89 form a blocking oscillator which when triggered with Q2 conducting will remain conducting for the time required to saturate the transformer 89. The selection of the transformer, of course, will be determined by the amount of dead time desired. In the instant application of the invention this would be 30 milliseconds. During the conducting period of the blocking oscillator it cannot be retriggered, thus providing the dead time. It should be noted that when transistor Q2 turns off, the voltage on the lead 92 rises well above the potential of the positive battery supply 100. The series diode 93 thereby protects the base emitter junction of transistor Q2. This series diode 93 is preferred to shunt diode approach because if a shunting diode were employed, while dead time might be increased by as much as 10 milliseconds due to discharge of the transformer 89 through the shunting diode, should the shunting diode fall off or become disconnected, then the dead time would suddenly decrease by 10 milliseconds. This would result in an unsafe condition especially if the 10 millisecond loss cut into the desired dead time required under dry ballast conditions.

The output from the blocking oscillator which is comprised of transformer 89 and transistor Q2 is a positive going square wave appearing on lead 103. Electrically coupled to lead 103 is a differentiator which includes the lead 107, capacitor 108, gate lead 109, and a resistor 111 which is connected to ground. The leading edge of the square wave above noted is differentiated which results in a positive going spike which will be employed to trigger the silicon-controlled rectifier (SCR) 110. A diode 112 is electrically connected to gate lead 109 and provides a similar protective function for silicon-controlled rectifier 110 as was described with reference to diode 77 and transistor Q1. The diode 112 also assures an electrical path to ground when the trailing edge of the square wave pulse from the blocking oscillator is differentiated to produce a negative going spike. The silicon-controlled rectifier 110 is electrically connected in a circuit between the positive battery terminal 100 and ground via lead 113, resistor 114, lead 116, lead 117, the silicon-controlled rectifier 110, and finally to ground. When the spike pulse due to the differentiation of the leading edge of the square wave output from transistor Q2 of the blocking oscillator appears on gate lead 109, this triggers silicon-controlled rectifier 110 into conduction. The silicon-controlled rectifier 110 once conducting will remain conducting until the voltage bias between the anode and cathode of the silicon-controlled rectifier falls below zero, at which time the silicon-controlled rectifier 110 will cease to conduct.

At the instant the silicon-controlled rectifier 110 starts to conduct, there will be present on capacitor 118 a charge due to the battery potential on terminal 100 electrically connected thereto by lead 113, resistance 114, and lead 116. The capacitor 118 will dump its charge through the silicon-controlled rectifier 110 to ground and in so doing, because of the electrical connection of the capacitor 110 by lead 119, inductor 121, lead 122 to transformer 123, will induce in the secondary winding of the transformer 123, an output pulse which approximates a half sine wave which will be passed by to lead 26*a* and thence over lead 26 to rail 11 where it will appear as repeater pulse 36.

It should be kept in mind that the combination of the capacitor 118, the inductor 121 and the transformer 123 plays three important simultaneous functions. The first of these is the assurance that the silicon-controlled rectifier 110 will experience a reverse polarity thus insuring that the silicon-controlled rectifier 110 will be turned off. In addition, there is established the size of the output current so that the circuit behavior is changed very little by a short circuit across the output. This is accomplished because the current through the inductor 121 and capacitor 118 is oscillatory, so that the voltage across the capacitor 118 will run down through zero during the pulse and then overshoot by a small amount of a few volts. While this arrangement of an inductor and capacitor in an oscillating circuit may be considered to be inefficient from the standpoint that a portion of the available pulse stored by the capacitor is used up internally in the capacitor and inductor, the highly desirable feature of being able to short the output without damage to the circuit is present. This is because the current is almost wholly determined by the inductor 121. In the railway environment in which this invention is to be employed, the problem of a possible short between the turns of the inductor, which would result in a very large output pulse which is unsafe, is avoided because the inductor 121 is made from a few turns of heavy well-insulated wire wound on a core and a nonshorting can.

By way of brief review it is seen that the track circuit of the instant invention provides a fail-safe arrangement whereby track circuits of great length may be attained with a high quality of circuit integrity heretofore unattainable over great distances. In addition, the presence of additional capacitance coupling of the rails further enhances the performance of the instant invention and may in fact be considered of singular value in the advancement of the art.

Having described the preferred embodiment of the invention it is desired that the invention not be limited to the specific construction set forth inasmuch as it is apparent that many additional modifications may be made without departing from the broad spirit and scope of the invention.

Having thus described my invention, what I claim is:

1. A track circuit for use with electrically continuous rails, including in combination,
   a. a signal-generating transmitter electrically coupled to said rails at a first point,
   b. a signal receiver electrically coupled to said rails at a second point,
   c. at least a first and a second signal-repeating means directly electrically coupled across said electrically continuous rails at points intermediate said first and said second point, said first signal-repeating means to receive and repeat a signal from said signal-generating transmitter to said second signal-repeating means which repeats said signal to be received by said signal receiver,
   d. each of said signal-repeating means including input means electrically coupled to said electrically continuous rails to receive said signal to be repeated,
      1. signal-repeating output means electrically coupled to said electrically continuous rails to provide said repeated signal,
      2. control means electrically coupled respectively to said input means and said signal-repeating output means to thereby initiate said repeated signal while simultaneously providing a period of nonresponse for said repeater for a predetermined period of time after said signal is received and repeated.

2. The track circuit of claim 1 which further includes more than two of said signal-repeating means directly electrically coupled across said rails at points which are intermediate said first point and said second point, each signal-repeating means capable of receiving a transmitted signal present in said rails and transmitting a repeated signal back into said rails.

3. The track circuit of claim 2 which further includes a plurality of capacitors electrically coupled across said rails intermediate said signal-generating transmitter, said repeater means and said signal receiver,

said capacitors providing improved signal transmission through said rail by reducing signal attenuation along said rails.

4. The track circuit of claim 1 wherein said signal generating transmitter is a pulse-generating transmitter and said repeater means transmits a repeated pulse.

5. The track circuit of claim 3 wherein said capacitors are uniformly spaced apart between said first point and said second point.

6. The track circuit of claim 3 wherein said capacitors are unevenly distributed along and between said rails to provide zones where there is an increased number of capacitors between said rails to improve signal propagation through said zones where ballast conditions upon which the rails of said track circuit are laid are adversely affected by changes in weather and inherently poor ballast conditions due to terrain.

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