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TRAFFIC CONTROL BY RADAR
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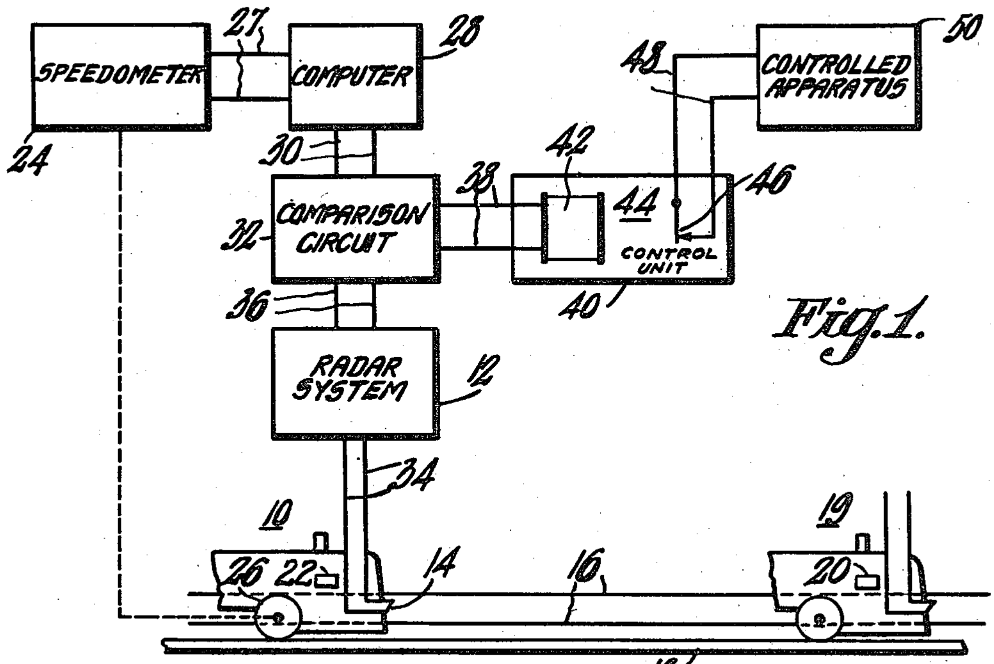


Fig.1.

Fig.1A.

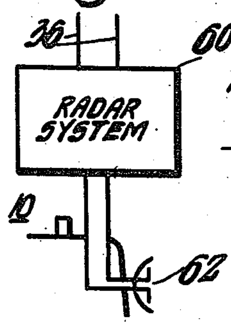


Fig.2.

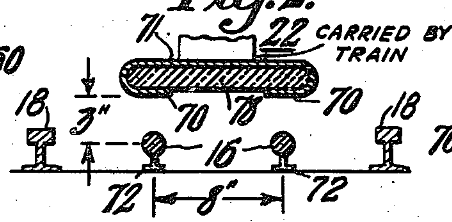


Fig.3.

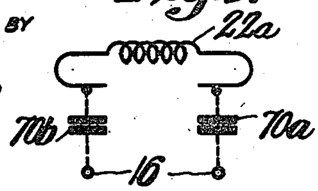
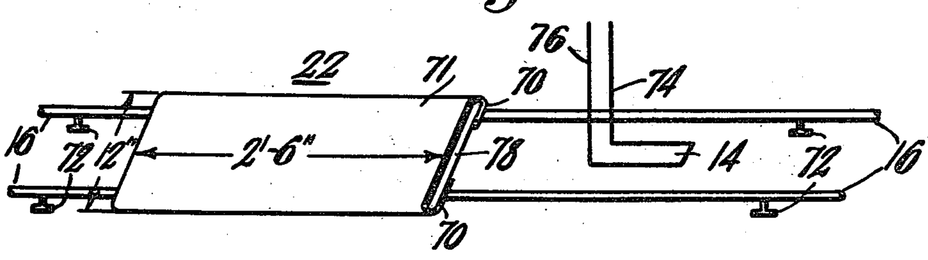


Fig.4.



INVENTOR
Nathaniel I. Korman
BY J. L. Whittaker
ATTORNEY

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TRAFFIC CONTROL BY RADAR

Nathaniel I. Korman, Merchantville, N. J., assignor to Radio Corporation of America, a corporation of Delaware

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3 Claims. (Cl. 246—30)

This invention relates to traffic control and more particularly to vehicular traffic control.

Railway traffic control systems heretofore proposed generally employ a block system. The right of way is divided into a series of blocks. Signals are placed at the entrance of each block length. The signals are actuated, usually by electrical means, in such a fashion that a stop signal is displayed a certain number of blocks to the rear of any train, and a warning signal a certain further number of blocks to the rear of a train. The warning signals may be passed at slow speed, but if the passing train traverses in less than a fixed time the block at the entrance of which the warning signal is displayed, the passing train will be stopped at the entrance to the succeeding block. This conventional block system requires considerable interblock wiring. Moreover, maximum usage of the track or right of way does not always result because of the fixed lengths of the blocks. The blocks must be of such a length that a train going at the greatest contemplated speed may be safely stopped within a certain number of block lengths. Therefore, the train may be forced to traverse an entire block length at slow speed, when the obstacle to more rapid travel may have been removed. The system is inflexible because the block lengths are fixed. Further, the signals displayed at the entrance of each block are ordinarily visual and in weather of poor visibility these signals cannot always be seen or observed with certainty by the operator of a rapidly moving train. These problems are particularly serious for municipal transit and subway systems where maximum track usage, close spacing, speed of travel, and safety factors are important from the standpoint of investment return and traffic congestion relief.

It is an object of the invention to provide a novel traffic control system and a novel method of traffic control.

It is a further object of the invention to make the most efficient use of a traffic right of way.

It is a further object of the invention to improve traffic control and particularly to improve railway traffic control.

It is a still further object of the invention to control vehicular traffic taking into consideration in the control thereof the speed of the vehicles.

It is another object of the invention to provide a traffic control system the signals of which may be clearly visible for traffic control even though adverse weather conditions with regard to visibility may prevail.

Another object of the invention is to provide a block control system of variable block length.

A still further object of the invention is to provide a novel control system which may supplement existing traffic control signals.

The invention may be used for the control of traffic in other than railway traffic control systems, wherever it is desirable to establish an assured clear distance for the vehicles or objects, the traffic of which is to be controlled.

Therefore, it is a broader object of the invention to provide a method and system for controlling the traffic of vehicular objects generally, whether along an established right of way or not.

In accordance with the invention a distance from a vehicle on the right of way is established which is dependent on the vehicle's speed and which may be dependent on the relative velocity of a vehicle and another in advance thereof, and the following vehicle is controlled in accordance with the presence or absence of an object detected within the said distance. Such control may be exercised by signals observed by the operator of the vehicle, or by automatic devices if desired. Preferably, the invention utilizes a radar system (which is defined herein as a radiation echo detection and ranging device) the system being carried by a vehicle to be controlled. The radar system develops a voltage dependent on the distance to the preceding vehicle. This voltage is compared with a voltage dependent on the velocity of the vehicle. The controlling vehicle is controlled in accordance with the results of the comparison. The radar system preferably radiates electromagnetic radiation on a transmission line along the right of way. To avoid ambiguities, it is essential that the radiation be directed unidirectionally along the transmission line. If such radiation is not unidirectional, signals from a train following the controlled train may be confused with those preceding it. In order to accomplish this unidirectional transmission and assure suitable reflection from the preceding train, an efficient reflecting device not in contact with the transmission line is highly desirable.

Accordingly, it is a further object of the invention to provide a novel short-circuiting device for a two conductor transmission line which is not in direct contact with the line.

It is a further object of the invention to develop such a short-circuiting device for a two conductor parallel transmission line.

In accordance with this feature of the invention, the short-circuit device includes a conducting plate spaced from the two conductor transmission line so that it is series-resonant in a transverse direction and also having a length to be resonant in a longitudinal direction along the line. Co-pending application Serial No. 243,084, filed August 22, 1951, now abandoned, as a division of this application, is directed to and claims the novel short circuiting element.

The various foregoing and other objects, advantages and novel features of the invention will be more fully apparent from the following description when taken in connection with the accompanying drawing in which like numerals refer to like parts:

Fig. 1 is a schematic diagram of a preferred embodiment of the invention utilizing guided electromagnetic energy and including the novel short-circuiting element hereinbefore mentioned;

Fig. 1*a* is a schematic diagram of a portion of an embodiment which may utilize supersonic radiation;

Fig. 2 is a cross sectional view of the transmission line and the short-circuiting element in relationship therewith;

Fig. 3 is a schematic circuit diagram showing the equivalent circuit electrically in a transverse direction of the transmission line; and

Fig. 4 is a perspective view of the short-circuiting element, transmission line, and coupling between the radar system and the transmission line.

Referring now to Fig. 1, a train **10** carries a radar system **12** connected to a coupling loop **14**. Coupling loop **14** is coupled to a parallel two conductor transmission line **16** which extends between the tracks **18** on which train **10** is shown. Train **19** is a preceding train which may be equipped with a control system similar to the equipment carried by train **10** and, in particular, employing a short-circuiting element **20** similar to the element **22** carried by train **10**. The particular utility of such an arrangement will be more fully apparent hereinafter. A speedometer **24** is coupled mechanically to a wheel **26** of train **10** or to an axle of the wheel. Such a speedometer may be, for example, a direct current generator which, over substantially the entire range of the expected angular velocity of the shaft thereof, may produce a D.-C. voltage directly proportioned to the angular velocity of the shaft. The shaft may be geared to the axle of wheel **26**. Such a voltage is a measure of the velocity of train **10** and may be fed through a connection **27** to a computer circuit **28** and thence through a connection **30** to comparison circuit **32**. Computer **28** may develop a voltage at connection **30** which is any desired function of the voltage fed to it through connection **27**. Such computers are well known and take many different forms.

The computer may comprise vacuum tubes. It may be in the form of a specially wound potentiometer across the fixed resistance of which is a fixed voltage supply. The movable contact of the potentiometer may be affixed to a shaft the rotation of which is controlled by a D.-C. motor. Such control may be exercised to cause the shaft rotation to be directly proportional to the voltage from the speedometer. This may be accomplished by coupling the shaft to the movable arm of a second potentiometer across which is a fixed D.-C. voltage. The voltage from this arm of the second potentiometer may be connected to oppose the voltage from connection 26 in opposition, and the difference voltage, amplified if desired, may be connected to the armature of the D.-C. voltage in a sense to cause the motor to turn to reduce the difference voltage to zero. The angle of shaft rotation then follows and corresponds to the speedometer voltage and the speed of the train linearly. From the tap of the first potentiometer may be obtained a voltage having any desired functional relationship to the train speed depending on the way in which the specially wound first potentiometer's resistance varies with its movable arm motion. Other equivalents both simpler and more complex for the arrangement will readily suggest themselves to those skilled in the art. For example, more simply, the speedometer 24 may be a governor coupled to wheel 26, connection 27 may be a mechanical linkage to the governor to govern the rotation of the shaft of a specially wound potentiometer.

Computer 28 preferably derives a voltage which is such a function of the train speed that it is proportional to, or at least always greater than the voltage representation of the assured clear distance in advance of the train. The function may be empirical, that is, based on experiments, and may include considerations of the operator's reaction time between a signal and brake application after observing a warning signal, the time required for the train to stop after application of the brakes, which latter time may vary in accordance with some function of train speed, and the like.

Radar system 12 is in this case a radio echo detection and ranging unit. High frequency electromagnetic energy is coupled through a connection 34 from system 12 to coupling loop 14. I prefer to use a pulsed radar system, of which many types are known. The pulsed radio-frequency energy is fed from loop 14 to transmission line 16. Short-circuiting element 22 is placed behind loop 14 so that, electrically, it may be said that the short-circuit is electrically substantially a quarter wavelength ($\lambda/4$) at the operating frequency to the rear of the point of effective coupling to transmission line 16 by loop 14. Therefore, the short-circuiting element prevents the passage of the energy to the rear of train 10 and directs the reflected energy forward in phase relation to aid the forward-going energy coupled to transmission line 16 by loop 14. The pulse of radio frequency energy thus directed forward and guided by transmission line 16 continues until it meets a radiation reflecting object, and because of the short-circuiting effect of element 20 on the preceding vehicle is reflected with certainty from the preceding train 19. It is now clear that element 20 insures a reflection from the nearest train 19 preceding train 10 and substantially prevents reflections appearing from objects in advance of train 19 because substantially no energy passes backwardly beyond the element 20.

Element 20, or a direct short-circuit might be used across transmission line 16 at specified points to simulate a radiation reflecting train and may be considered as a radiation reflecting obstacle even though it is only a simulated obstacle. The energy reflected from element 20 is returned along transmission line 16 and coupled to the radar system 12 by coupling loop 14. As well known, the radar system then measures the time elapsed between the transmission of the original pulse of energy to its reception or detection and thereby measures the distance between trains 10 and 19.

As will be readily recognized by those skilled in the art, a voltage may be developed by radar system 12 which is proportional to or dependent on this distance between trains. This voltage, for example a D. C. voltage, may be appropriately filtered and is connected by connection 36 to comparison circuit 32. One simple manner of developing such voltage, for example, is to provide a resistor-capacitor combination in series, a D.-C. voltage supply to feed the combination through a tube, and circuits to start the tube conducting at the initiation of each of the

pulses of radio frequency energy of the radar system, and to stop the conduction at the reception of the detected reflection. The capacitor voltage thus charges to a value dependent on the elapsed time between these pulses which is proportional to the distance. This D.-C. voltage across the capacitor may then be filtered and applied to connection 36. The filter may assure discharge of the capacitor at a satisfactory rate as the distance between trains 10 and 19 decreases.

The comparison circuit 32 compares the two voltages: the one developed by computer 28 which is dependent on the velocity of train 10 and the other derived from the radar system 12 which is dependent on the distance from train 10 to the nearest radiation reflecting object. Comparison circuit 32 is connected by connection 38 to control unit 40 which is responsive to the comparison made between these two voltages. The comparison may merely determine whether the voltage at connection 30 exceeds the voltage at connection 36, in which case a voltage is applied to connection 38 to energize the relay winding 42 to actuate the relay 44. On the application of voltage to winding 42 and the flow of current therethrough, contacts 46 may be broken, with the resultant actuation through connection 48 of any desired control apparatus 50, for example, signal lights, brakes, or the like.

Instead of utilizing a radar system 12 of the type employing electromagnetic radiation, one may employ, as shown in Fig. 1*a*, a radar system 60 which may radiate supersonic radiation directed forward of train 10 by a parabolic dish reflector 62. Suitable transducer means are known to produce such radiation near the focus of the dish. Electromagnetic radiation again may be used if the dish reflector 62 is conductively surfaced and a suitable radiating element and transducer are used. I prefer the system of Fig. 1 using guided transmission because extraneous reflections from objects which may be along the roadside will not affect the operation of the system, and because the radiation can be more easily guided around curves. However, along an open space or plane area not surrounded by reflecting objects, a radar system such as 60 might be used.

By analogy to prior block systems, it may be said that the speedometer and computer establish a block length in advance of each train carrying the equipment, the block length being variable with the speed of the vehicle. In the above examples, this block length is continuously variable with the vehicle speed.

Referring now to Figs. 2 and 4, short-circuit element 22 is suspended over transmission line 16 in spaced relationship therewith, in which position it is carried by train 10. Element 22 is a plate having side portions 70 folded under it.

The operation of the short-circuiting element will be clear from Fig. 3 where its equivalent circuit transversely is illustrated schematically. The side portions 70 of element 22 are folded under as shown in Figs. 2 and 4, between the track and central portion 71 of element 22 and each side portion is in capacitive relationship with one of the conductors of transmission line 16 as indicated by capacities 70*a* and 70*b* of Fig. 3. The central portion 71, transversely, of element 22 may be considered as an inductance 22*a*. It will be apparent that at some frequency there is a series resonance with capacities 70*a*, and 70*b* resonating with inductance 22*a* to produce a series short-circuit between the conductors of line 16. Moreover, the element 22 is made electrically a quarter wave length long to be resonant in a longitudinal direction along the line at this same frequency. The approximate dimensions of the coupling element for a particular transmission line are shown in Fig. 4. For a frequency of 100 megacycles (a wavelength of about 10 feet) element 22 is 2½ feet longitudinally and transversely about 12 inches at its widest. The spacing from the ends of element 70 to transmission line 16 is designed for a normal clearance of 3 inches and will perform fairly well for clearances between 2 and 4 inches. The transmission line 16 typically consists of two one inch diameter conductors spaced 8 inches between centers, and supported on stand off insulators 72. The coupling loop 14 inductively couples to the transmission line by being suspended with parallel wires 74 and 76 closely adjacent to the conductors so that the current through the loop 14 induces a voltage in the conductors of line 16. If desired, the space within the folded sides 70 and the central portion 71 of element 22 may be filled with a solid dielectric 78, which adds to the rigidity and ruggedness of the element. By this spaced short-circuiting element, wear on transmission line **16** is avoided, whereas a direct contact short-circuiting element would cause considerable wear on the transmission lines. With practically no wear the transmission line may be made of steel plated with only a coating of relatively highly conductive metal, say copper, at a considerable saving.

It will be apparent that the system and method described hereinabove provides an economical means of traffic control whereby the controlled apparatus, for example, a signal light, may be carried in the cab of a train and its visibility to the operator will not be adversely affected by weather conditions of poor visibility such as fog and the like. Moreover, by the computer and comparison circuits it will be apparent that the signal of danger or the application of brakes may be deferred until such time as the assured clear distance ahead of the train is greater than the distance within which a radiation reflecting obstacle, real or simulated, may be positioned in advance of the control vehicle. The novel shorting element in combination with the radiating elements or coupling assures that there will be no ambiguity in the direction in which the distance to the nearest obstacle is measured. It will be observed that in practicing the invention, the velocity of a train is measured, a distance dependent thereon and preferably equal to the assured clear distance in advance of the train is established, the distance to the nearest obstacle in advance of the train is measured, and the established distance and the measured distance are compared for control purposes. In effect a variable block distance is established, the distance varying with the speed of the vehicle. It will also be observed that the system herein disclosed is entirely independent of the conventional block systems, and therefore may be used either to supplement or replace the conventional systems.

What I claim is:

1. In a system for the control of vehicular traffic, means for deriving a control voltage comprising means on a vehicle for deriving a first voltage that increases in value as a function of increasing ground velocity of the vehicle, means on the vehicle for deriving a second voltage by radiation echo detection and ranging that increases in value as a function of increasing distance of the nearest obstacle in advance of said vehicle, control apparatus, and means for actuating said control apparatus in response to the value of said first voltage exceeding the value of said second voltage.

2. In a system for the control of vehicular traffic, means for deriving a control voltage comprising means on a vehicle for deriving a first voltage having a value proportional to the ground velocity of the vehicle, means on the vehicle for deriving a second voltage by radiation echo detection and ranging having a value proportional to the distance of the nearest obstacle in advance of said vehicle, and comparison means for subtracting said second voltage from said first voltage whereby a control voltage is obtained when said first voltage exceeds said second voltage in value, control apparatus, and means for actuating said control apparatus in response to the occurrence of said control voltage.

3. In a system for the control of vehicular traffic, means for deriving a control voltage comprising means on a vehicle for deriving a first voltage that increases in value as the ground velocity of the vehicle increases, means on the vehicle for deriving a second voltage by radiation echo detection and ranging that increases in value as the distance of the nearest obstacle in advance of said vehicle increases, comparison circuit means for supplying a control voltage in response to and only in response to the value of said first voltage exceeding the value of said second voltage, a control device, and means for actuating said control device in response to the occurrence of said control voltage.

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