AUTOMATIC VEHICLE MONITORING SYSTEM

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References Cited
UNITED STATES PATENTS
3,633,158 1/1972 Heibel.............................. 250/199
2,904,674 9/1959 Crawford.......................... 343/100 CS
3,474,460 10/1969 Huebscher ....................... 343/6.8 R
3,419,865 12/1968 Chisholm ....................... 340/24

OTHER PUBLICATIONS

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ABSTRACT

A cooperative fleet vehicle location monitoring system utilizes low-energy-level coded impulse transmissions characterizing possible vehicle locations along a route to permit an impulse receiver aboard the cooperating vehicle to cause generation of coded transmissions receivable at a headquarters control location repeatedly identifying the vehicle and its location.

10 Claims, 14 Drawing Figures
FIG. 9.
AUTOMATIC VEHICLE MONITORING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention
The invention pertains to apparatus permitting rapid automatic monitoring of the location of cooperating vehicles of a fleet and more particularly relates to an impulse communication system for identifying the location of each cooperatively equipped vehicle as it passes selected electronically instrumented locations on its route.

2. Description of the Prior Art
Operators of fleets of vehicles in urban environments, including emergency vehicles, have need of a general purpose system for rapid monitoring at a control headquarters location of the locations of fleet vehicles. Typical operators facing the need are operators of fleets of vehicles such as police, fire, bus, taxi, delivery truck, ambulance, armored carrier, mass transport, utility repair, and security guard patrol vehicles. Rapid location monitoring has not been available for effective fleet management, roll call, scheduling and headway control, optimum dispatching, priority routing, and crime deterrence. Effective means for the monitoring of locations of large vehicle fleets, often totaling as many as a thousand vehicles and often scattered over large urban areas, has not been possible. Even the widely spread call box system and two-way radio transmission systems employed in emergency vehicles and sometimes in mass transportation carriers are expensive and time consuming to use. Reporting at frequent intervals distracts the vehicle operator from attention to proper operation of his vehicle and is therefore unsuitable in emergency situations. Yet it is always in major emergency situations that effective monitoring is most needed, for instance, to bring police or other vehicles into proper convergence to surround a region of major disturbance, or to route fire equipment to a major fire safely along separated routes so that collisions between fire fighting vehicles are not risked. Fully effective monitoring of the locations of elements of commercial fleets is clearly also desirable as a tool permitting maximum economic use and maximum high-jack resistant operation of such commercial vehicles.

SUMMARY OF THE INVENTION
The invention is an impulse radio communication system using low-energy-level coded impulse transmitters and impulse receivers for signalling the presence of fleet vehicles at selected locations as they progress along a route. Coded fleet vehicle identity and location data is transmitted from the vehicle to a central headquarters location from which instructions may be issued to individual vehicle drivers over conventional broadcast equipment.

BRIEF DESCRIPTION OF THE DRAWINGS
FIG. 1 is a perspective view of a typical urban intersection equipped to operate according to the present invention.
FIG. 2 is a map of a network of streets useful in explaining the operation of the invention.
FIG. 3 is a perspective view, partly in cross section, showing the external appearance of an impulse transmitter-antenna configuration used in the invention.
FIG. 4 is an equivalent circuit of the apparatus of FIG. 3.

FIGS. 5a, 5b, 6a, 6b, 7a, 7b, 8a, and 8b are graphs useful in explaining the operation of the transmitter-antenna configuration of FIGS. 3 and 4.
FIG. 9 is a block diagram of a preferred impulse receiver for use in the invention.
FIG. 10 is an alternative form of an impulse antenna for use in the impulse receiver of FIG. 9.

DESCRIPTION OF THE PREFERRED EMBODIMENT
FIG. 1 illustrates a representative situation in which a cooperating fleet vehicle 6 is present in an urban street intersection area illuminated continuously by a train of electromagnetic impulse transmissions provided by an impulse transmitter-antenna configuration 1 mounted for example, in the novel system on a street lamp standard 2 supported by a street lamp pole 3. Other transmitter-antenna configurations like configuration 1 may be located at other street intersections or at any other selected area location which may be traversed over by the cooperating fleet vehicle 6. If desired, directive transmitter-antenna configurations like device 1 may be suspended from buildings and may otherwise be arranged to be hidden or unrecognized by those having no basis for knowing of their presence. Each transmitter-antenna configuration is characterized by emitting impulses having an impulse repetition frequency peculiar to its particular location.

A cooperating fleet vehicle, such as the emergency vehicle 6, is equipped with a radome-protected antenna 8 specially designed for receiving the impulse transmissions of each transmitter-antenna configuration 1 as the area illuminated by the latter is traversed by the vehicle. Reception, therefore, of an impulse wave train of a particular repetition frequency identifies the location being traversed by the vehicle at the moment of reception. Reception of the impulse wave by novel radio receiver equipment coupled to antenna 8 may cause broadcast of identification information by a conventional communication transceiver antenna 7 to a central headquarters, thus informing such a central command post instantaneously of the presence of emergency vehicle 6 at, for example, the intersection of 9th Street and I Street.

As seen in FIG. 2, the pole 3 on which the transmitter-antenna configuration 1 of FIG. 1 is located at 9th Street and I Street is placed on one corner of a common type of right angle street intersection in such a way that impulse radiation from the transmitter-antenna 1 generally covers an area indicated for convenience by circular boundary 3a, a boundary which generally may be other than truly circular. It is to be understood that the center of the illuminated area will not necessarily define the location of the transmitter-antenna 1. If I Street is too to be furnished with a generally regular array of monitored intersections, other directive antenna-transmitter apparatus 1 according to FIGS. 3 and 4 may be placed on street lamp poles 10 and 11, for example, for illuminating the respective areas 10a and 11a with impulse radiation. It is thus seen that the successive intersections of I Street with 9th, 10th, and 11th Streets are served and that a cooperating vehicle moving along I Street will enter areas of illumination by impulse energy of successively different impulse repetition frequencies. The area of effective illumination, for example, at the 9th Street and I Street has a maximum dimension of substantially 200 feet.
Such an area of illumination is also sufficient, for example, to cover the various proximate intersections of 1 Street, 10th Street, and Boulevard A from a centrally placed transmitter-antenna system I on street light pole 16. If more of Boulevard A is to be serviced by the system, non-overflowing illumination areas 12a and 13a may be similarly produced at the intersections of Boulevard A and J Street and of Boulevard A and 11th Street. A cooperating vehicle passing along Boulevard A will then meet successive impulse energy illuminated areas 12a, 16a, and 13a, each having a distinctive impulsive repetition frequency.

An antenna-transmitter system for use as configuration I in the novel system of FIG. 1 is of a special type to be discussed in connection with FIGS. 3 and 4. The configuration 1 employs an electrically smooth, constant impedance, transmission line system for propagating TEM mode electromagnetic waves. The transmission line system which is an improvement over that disclosed in the G.F. Ross et al., Patent application Ser. No. 46,079 for a “Balanced Radiator System,” filed June 15, 1970, issued Apr. 25, 1972 as U.S. Pat. No. 3,659,203, and assigned to the Sperry Rand Corporation, is employed for the cooperative cyclic storage of energy on the transmission line and for its cyclic release by propagation along the transmission line formed as a flared or tapered directive antenna. Thus, cooperative use is made of the transmission line system for signal generation by cyclically charging the transmission line at a rate determined by the distributed capacity C1 and resistors R1 and R1s, as will be seen, and for signal radiation into space by discharge of the line in a time much shorter than required for charging. Discharge of the transmission line causes a voltage wave to travel toward the open end or radiating aperture of the antenna structure. The process operates to produce, by differentiation, a sharp impulse that is radiated into space. The antenna system has a wide instantaneous bandwidth, so that it may radiate very sharp impulse-like signals with low distortion. Further, the antenna has an energy focusing characteristic such that energy radiated in predetermined direction is maximized.

The antenna-transmitter configuration I of FIGS. 3 and 4 comprises a structure having mirror image symmetry about a median plane at right angles to the direction of the vector of the electric field propagating within the antenna. The same is true of the cooperating transmission line 30 which comprises parallel plate or slab transmission line conductors 31 and 31a of similar shape. Conductors 31 and 31a are spaced planar conductors constructed of a material capable of conducting high frequency currents with substantially no ohmic loss. Further, conductors 31 and 31a are so constructed and arranged as to support TEM mode propagation of high frequency energy, with the major portion of the electric field lying between conductors 31 and 31a and with the electric field substantially perpendicular to the major interior surfaces thereof.

The TEM transmitter-antenna 1 further consists of a pair of flared, flat, electrically conducting planar members 32 and 32a. Members 32 and 32a are, for example, generally triangular in shape, member 32 being bounded by flared edges 33 and 33a and a frontal aperture edge 34. Similarly, member 32a is bounded by flaring edges 35 and 35a and a frontal aperture edge 36a. Edges 34 and 34a may be straight or arcuate. Each of triangular members 32 and 32a is slightly truncated at its apex, the truncation being so constructed and arranged that conductor 31 is smoothly joined without overlap at junction 36 to antenna member 32. Likewise, conductor 31a is smoothly joined without overlap at junction 36a to antenna member 32a. It is to be understood that the respective junctions 36 and 36a are formed using conventionally available techniques for minimizing any impedance discontinuity corresponding to the junctions 36 and 36a.

It is also to be understood that the flared members 32 and 32a of antenna I are constructed of material highly conductive to high frequency currents. It is further apparent that the interior volume of transmitter-antenna I may be filled with an air-foamed dielectric material exhibiting low loss in the presence of high frequency fields. The interior of transmission line 30 may be similarly filled with dielectric material, such material acting to support conductor 31 in fixed relation to conductor 31a and, likewise, the flared antenna member 32 relative to flared member 32a. Alternatively, the conductive elements of transmission line 30 and transmitter-antenna 1 may be fixed in spaced relation by dielectric spacers which cooperate in forming enclosing walls for the configuration, protecting the interior conducting surfaces of antenna-transmitter configuration I from the effects of precipitation and corrosion. For example, thin vertical walls 38 and 38a of low loss dielectric sheet material may be used in conjunction with transmission line conductors 31 and 31a. Side walls for separating the horn elements 32 and 32a may take the form of triangular low loss dielectric wall elements 39 and 39a; such side walls, in cooperation with a thin, radome wall 40 of low loss dielectric material, lend mechanical strength to the transmitter-antenna configuration I and aid in protecting the interior thereof. It will be understood that the elements 32 and 32a forming the antenna aperture may be exponentially tapered, as indicated in FIG. 4, as well as linearly tapered.

A form such as that of the transmission line 30 and the transmitter-antenna 1 as illustrated in FIG. 3 is preferred, in part, because TEM mode propagation therein is readily established. The TEM propagation mode is preferred, since it is the substantially non-dispersive propagation mode and its use therefore minimizes distortion of the propagating signal to be transmitted. The simple, balanced transmission line structure permits construction of the configuration 1 with minimum impedance discontinuities. Furthermore, it is a property of the symmetric type of transmission line of antenna-transmitter 1 that its characteristic impedance is a function of b/h, where b is the width dimension of the major surfaces of conductors 32, 32a and h is the distance between the inner faces of the conductors 32 and 32a. For example, the ratio b/h is kept constant in the instance of transmission line 30 because both b and h are constant.

According to the invention, the transmitter-antenna 1 is made compatible with transmission line 30 by using the same value of the ratio b/h for both elements. In other words, if the ratio b/h is kept constant along the direction of propagation in transmitter-antenna 1, the characteristic impedance of transmitter-antenna 1 will be constant along its length and may readily be made equal to that of line 30. By maintaining a continuously constant characteristic impedance along the structure including line 30 and transmitter-antenna 1, frequency sensitive reflections are prevented therein. It has been
elected, for the sake of simplicity of explanation, to show in FIG. 3 triangular flaring planar configurations for elements 32 and 32a. It should be evident, however, that other configurations may readily be realized which maintain a constant characteristic impedance according to the above rule, and that such configurations may also be used within the scope of the present invention.

The system for exciting the transmitter-antenna 1 of FIG. 3 has compatible properties, such as being balanced in nature and as avoiding the complicating deficiencies of an interface balun or other transition element. The system of FIG. 4 achieves such objectives and, in addition, makes beneficial use of the balanced dual element configuration of transmitter-antenna 1 as part of the charging line for the excitation generator. It will be understood that certain liberties have been taken in the drawing of FIG. 4 better to explain the structure and operation of the device disclosed therein. For example, it is seen that FIG. 4 is intended schematically to indicate conductor elements 32 and 32a of FIG. 3 as a respective single wire transmission lines 42 and 42a having the same effective electrical characteristics as elements 32 and 32a of FIG. 3 and the same radiating characteristic. As a further example, junctions 36 and 36a in FIG. 3 are represented by junctions 46 and 46a in FIG. 4. The symbols 31 and 31a in FIG. 3 are represented in FIG. 4 by symbols 41 and 41a and identify the opposed conductors of transmission line 30. Dimensions in FIG. 4 are exaggerated, such as the spacing h between conductors 41a and 41a of line 30, as a matter of convenience.

At the left end of line 30, conductors 41 and 41a are joined by a series circuit comprising battery 50 coupled between charging resistors 51 and 51a each having a resistance value R/2 ohms. At the end of line 30 adja cent junctions 46 and 46a, the conductors 41 and 41a are joined by a series circuit comprising an electrically actuable switch 52, which may take the form of an avalanche transistor or other transistor switch; thus, transistor 52 is coupled across battery 50 through resistors 51, 51a, 56, and 56a. Also coupled across battery 50 is an astable multivibrator 54 which is connected through capacitor 53 to the base of transistor 52 for the purpose of controlling the state of conduction of transistor 52. Resistors 56 and 56a each have a resistance value of r/2 ohms, where r is equal to the characteristic impedance of line 30 (and of the transmission line comprising elements 42 and 42a). Transistor 52 is also provided with a base-to-ground resistor 53a.

Astable multivibrator or pulse generator 54 produces a regular bipolar wave train such as wave 55, of a predetermined pulse repetition frequency for actuation of transistor switch 52. In operation, it will be observed that transistor switch 52 is first held non-conducting by pulse generator 54 for a time sufficient for the entire structure including the conductors of line 30 and conductors 42 and 42a to become charged to a potential difference V equal to that supplied by battery 50 as if charging an effective capacitor C. On the next cycle of wave 55, transistor switch 52 is rendered conducting, forming a conducting circuit path through resistors 56 and 56a. The effect is that of putting a second or effective source B in series with the first source A or battery 50, but reversed in polarity relative to the polarity of the first source A.

FIGS. 5a, 6a, 7a, and 8a show the positive voltage V, contributed by the source A or battery 50, as a positive constant voltage at successive intervals in the operating cycle. The same set of figures shows the progress of the negative wave due to the second or effective source B at the same successive intervals. For example, FIG. 5a shows the situation at the instant switch 52 is rendered conductive; note that the wave due to the effective second source B has not started to flow. In FIG. 6a, however, the negative wave of voltage \(-V/2\) from the effective second source B has begun to flow toward the aperture of transmitter-antenna 1. Upon reaching the ends 44, 44a of conductors 42 and 42a of FIG. 4, and upon being reflected, the situation is depicted in FIG. 7a. It is seen that when the \(-V/2\) wave reaches the respective ends 44, 44a of antenna conductors 42 and 42a, it is reflected and begins to flow back toward junctions 46, 46a. The total contribution of the second of effective source B, beginning at the instant of reversal, is now \(-V\) volts. It will be seen that the total potential due to the real and the effective sources A and B between conductors 42 and 42a at the aperture 44, 44a of the antenna at the instant of reversal suddenly drops from \(+V\) volts to zero; this instant of time is one of primary interest in the operation of the transmitter-antenna 1. The wave due to the effective source B continues to travel back toward junctions 46, 46a until the antenna conductors 42, 42a, which have served as part of the charging line for the system are substantially completely discharged, if the value of r is the characteristic impedance of the line comprising conductors 42, 42a. The charging cycle is then reestablished when pulse generator 54 renders switch 52 non-conductive again and the system may be repeatedly cycled.

It will be readily appreciated that the total potential difference seen across the aperture 44, 44a of the antenna, for the same successive instants of time as described above, may be illustrated as in the respective FIGS. 5a, 6a, 7a, and 8a. It is seen that the potential at the antenna aperture due to the real source 50 (or A) is progressively eaten away by the travel of the wave due to the second or effective source B started toward the aperture 44, 44a when switch 52 is conductive and then reflected at the aperture where radiation occurs ultimately to effect substantial discharge of the line formed by conductors 42 and 42a, the wave having returned to be absorbed in the resistances 56, 56a.

As noted previously, it is the instant of reflection of the wave of the effective source B at the distance L along conductors 42 and 42a (the aperture of transmitter-antenna 1) that is of prime interest. Because of the finite characteristic impedance r of the transmitter-antenna system, the leading edge of this \(-V/2\) wave launched into the aperture or mouth of the antenna, which is in effect an open circuit, reverses in direction of flow while maintaining its previous polarity. Radiation into space of an impulse signal proportional to \(dV/dt\) must occur at this instant of time. No further radiation can obtain until after switch 52 is recycled and conductors 42 and 42a are charged. As noted above, if the resistance r of the sum of resistors 56 and 56a is made equal to the characteristic impedance of the transmission line system, the reflected wave front finally terminates in resistors 56, 56a and the potential difference across the entire line drops to substantially zero and then begins to recharge to approximately \(rV/R\) volts, recharging requiring \(2\pi rC_t\) seconds.
It will be appreciated by those skilled in the art that alternative ways are available for producing cyclic storage of energy in the transmission line systems of FIGS. 3 and 4 and for its release for propagation along the transmission line to an antenna radiating aperture. For example, mercury-wetted reed switches may be employed of the type disclosed in the H. Maguire U.S. Pat. application Ser. No. 652,656 for a "Coaxial Line Reed Switch Fast Rise Time Signal Generator with Attenuation Means Forming an Outer Section of the Line," filed Aug. 25, 1969, issued Feb. 16, 1971 as U.S. Pat. No. 3,564,277, and assigned to the Sperry Rand Corporation. Switches of the type disclosed in the G.F. Ross et al U.S. Pat. application Ser. No. 843,945 for a "High Frequency Switch," filed July 23, 1969, issued Mar. 9, 1971 as U.S. Pat. No. 3,569,877, and also assigned to the Sperry Rand Corporation, may be employed. The transistor switch 52 may be organized in the transmitter-antenna system in such a way that it is part of a self-exciting circuit. Such arrangements and others applicable in the present invention are discussed in the foregoing. G.F. Ross et al U.S. Pat. application Ser. No. 46,079 for a "Balanced Radiator System."

The omnidirectional bicone antenna 8 intended to receive impulse transmissions from transmitter-antenna 1 is seen in FIGS. 1 and 9 mounted within a cylindrical radome 63 on the roof 6a of the cooperating fleet vehicle. An alternative type of antenna illustrated in FIG. 10 may be used if the pulse repetition rate approaches the resonant frequency of the antenna. However, the omnidirectional antenna element shown in FIG. 9 maximizes the response amplitude with excessivly increasing the response time of the received signal. The antenna is composed of a conducting cone 61 with its apex pointed downwardly and supported so as to pend from the inner surface of a flat top portion 63a of dielectric radome 63. The apex of cone 61 is coupled to the inner conductor 62 of a short coaxial cable cooperating with the concentric outer conductor 62a. Conductors 62 and 62a comprise a coaxial transmission line projecting through a hole in the roof 6a of the fleet vehicle 6. In this way, the roof 6a forms a ground plane for antenna 8 in the conventional manner, enhancing the energy collecting efficiency of antenna 8.

Filter 65 is used to eliminate undesired relatively low frequency signals and to pass received impulse wave trains to a detector circuit featuring diode 69, which diode is coupled to ground and through series resistors 67 and 68 to a suitable source of bias voltage (not shown). Diode 69 is preferably a tunnel diode or other high speed diode adapted to serve as an impulse detector. A suitable diode has a negative resistance current-voltage characteristic such that, under proper bias, the diode response to the arrival of impulse emissions from the transmitter-antenna configuration 1 is to move abruptly into its region of instability, causing it to become highly conductive.

In this manner, a current impulse of somewhat greater amplitude but of considerably longer duration is generated by tunnel diode 69 and is coupled to the input of one shot multivibrator circuit 70; the longer duration, higher energy signal is required for reliable triggering of multivibrator 70. The output pulse of multivibrator 70 is a rectangular pulse of 100 nanosecond duration, for example, which is passed to AND gate 72. The 100 nanosecond pulse is coupled also by lead 71 to the junction 66 between bias control resistors 67 and 68. At junction 66, the trailing edge of the 100 nanosecond pulse has the effect of resetting diode 69 and of stopping conduction therethrough. Thus, tunnel diode 69 is reset to its original low conduction state and is prepared to receive the next arriving impulse from transmitter-antenna configuration 1 which exceeds the triggering level of diode 69. Accordingly, if the transmitter-antenna configuration 1 produces impulses at an impulse repetition frequency in the vicinity of 5 kilohertz, the output of multivibrator 70 is a pulse train of 100 nanosecond pulses having a repetition frequency of five kilohertz.

The output of one shot multivibrator circuit 70 is coupled to AND gate 72, to which a controlling signal from interrogator device 78 is also supplied. Interrogator device 78 may be operated regularly by a suitable digital or other clock at intervals of five seconds, at the will of the vehicle operator, or by a command signal received, for instance, from head-quarters by transceiver 75, and comprises any conventional pulse generating device suitable for supplying an interrogation pulse of predetermined length for proper control of the conventional AND gate 72. The duration of the interrogation pulse may be, for example, fixed at 500 milli-seconds. Thus, separated pulse trains are passed to counter circuit 73 by AND gate 72 as the vehicle moves along a serviced route. The pulses present in each such pulse train are counted by counter 73 for a standard time interval, counter 73 being a conventional counter circuit of the type adapted to count incoming pulses and to transfer the count to an encoder 74 at the end of the prescribed time interval or other condition.

A signal representing the pulse count in the predetermined time, and therefore identifying the corresponding location of the cooperating fleet vehicle 6, may be transmitted directly to central headquarters by the usual voice radio communication link already present within the vehicle, for example, by transceiver 75 and omnidirectional antenna 7.

In a preferred system, the pulse count in counter 73 may be automatically shifted out of counter 73 into a conventional encoder 74. Encoder 74 reduces the burden of transmission by transceiver 75 by converting the pulse count into an encoded representation thereof that is much simpler to transmit. Consequently, encoder 74 may be designed in a conventional manner also to cause transmission to the headquarters center of a pulse coded signal automatically identifying the particular fleet vehicle as it reports its location.

It is seen that the receiver of FIG. 9 is a wide band device; except for the presence of high pass filter 65, which may have, for example, a gigahertz cut-off frequency, the receiver would respond to any signal level in excess of, for example, the 80 millivolt level which might be dictated by the characteristics of a particular tunnel diode 69. The amplitude of the received impulse at the receiving antenna 8 is, or example, about 200 millivolts in the usual operating circumstance, a value several orders of magnitude greater than the signals present in an urban environment due to conventional radiation sources, such interfering signals normally being at the microvolt level. Accordingly, although the receiver of FIG. 9 essentially accepts all signals in the pass band of filter 65, it is substantially immune to interference from conventional radiation sources, includ-
ing electrical noise signals such as internal combustion engine ignition noise.

As has been observed in the foregoing discussion, the directive transmitter-antenna configuration 1 shown in FIGS. 3 and 4 is capable of transmitting a regular train of extremely short duration, high amplitude impulses. In a typical situation, these impulse-like signals have time durations of 200 picoseconds and an impulse repetition frequency in the order of 10 kilohertz. If the voltage applied by battery 9 of FIG. 4 is assumed to be 500 volts and the source impedance 50 ohms, then the upper bound on the average power transmitted into all of space is less than 1 microwatt. The spectrum of the transmitted signal is spread over an extremely wide band width, typically 100 megahertz to 10 gigahertz. Accordingly, the power radiated in any typical narrow communication band is far below the thermal noise threshold of a typical receiver operating in that band. The transmitted impulse is therefore incapable of interfering with the operation of standard radio communication equipment. Indeed, the operation of the transmitter-antenna configuration 1 is such as not to require governmental licensing under present regulations.

The conical antenna used in the receiver system of FIG. 9 best optimizes the maximum received signal and the minimum response time of any known omnidirectional receiving antenna. Other omnidirectional antennas can also be used when response time or amplitude limitations are not severe. In particular, when the pulse repetition frequency approaches 100 megahertz, a thin film top-hat-loaded antenna such as shown in FIG. 10 may be used. Such an antenna is disclosed in the G. F. Ross U.S. Pat. application Ser. No. 832,337 for a "Time Limited Impulse Response Antenna," filed June 11, 1969, issued June 22, 1971 as U.S. Pat. No. 3,587,107, and assigned to the Sperry Rand Corporation. Antennas that have a time limited impulse response do not ring, so as to cause interference with a succeeding input pulse.

In FIG. 10, the antenna is seen to be mounted on a ground plane 6a, which again represents the roof of the cooperating fleet vehicle, the antenna being coupled to a receiver system via coaxial line 62, 62a, as in FIG. 9. In FIG. 10, a thin resistive layer 90 formed of a thin chromium plating is positioned above and parallel to ground plane 6a. Resistive film 90 may be applied to a glass or dielectric disc 91. The coated plate 91 is preferably constituted of dielectric material and may in practice be the flat portion 63a of a radome 63 fully enclosing the antenna, as illustrated in FIG. 9. In other arrangements, resistive film 90 and the top disc 91 may very simply be supported upon a layer 92 of air foamed dielectric material of conventional nature, layer 91 thus performing the protective function of a radome.

A portion 93 of the central conductor 62 of coaxial line 62, 62a extends through dielectric layer 92 and joins resistive disc 90 substantially at its center. Resistive layer 90 is preferably constructed to have a radius approximately equal to the length of the portion 93 of conductor 62 found within dielectric layer 92. Typically, the resistive layer 90 has a radius greater than 200 times the diameter of conductor 93.

The operation of the antenna 8 of FIG. 10 is described in the above mentioned U.S. Pat. application Ser. No. 832,337, and is understood by assuming that an impulse plane-polarized wave with its electric factor oriented parallel to conductor 93 is caused to impinge on the antenna from the left in the drawing, as indicated by arrow 94. As the incoming impulse wave reaches the antenna, voltages are established between ground plane 6a and the resistive layer 90. When the incoming impulse wave first reaches the conductor 93, impulsive currents are produced at each infinitesimal segment of conductor 93 and flow downward toward the entrance to coaxial line 62, 62a. The induced currents also flow upward toward resistive layer 90, where any such are absorbed. The useful downward flowing current passes without reflection into coaxial line 62, 62a and is detected by diode 69. Because the upward flowing current is absorbed by resistive layer 90, it cannot be reflected downward subsequently to appear in coaxial line 62, 62a and thus distortion which would ordinarily be produced is substantially eliminated.

Accordingly, the monopole receiving antenna of FIG. 10 is equipped with a monopole conductor portion 93 of a length such that the voltage induced at its upper tip travels to its base adjacent ground plane 6a in a time substantially equal to the duration of the received impulse. The monopole element 93 extends between the aperture ground plane 6a and the thin resistive layer 90, the latter having a surface resistivity substantially equal to the impedance of free space. The resistive layer 90 also has a radius at least equal to the length of the monopole 93 so as to provide an essentially reflectionless termination for monopole 93 and substantially to eliminate distortion of the received electromagnetic impulse.

It is seen that the invention is an impulse radio communication system using very low total energy level, coded, transmitted impulses having a spectral content spread over a very wide band so as to make no significant contribution to the background electrical noise level and thus operating well below levels interfering with government controlled radio transmissions. The transmitters of the system are adapted to excite vehicle borne impulse receivers for identifying fleet vehicles, at the same time identifying their presence at selected locations along routes traversed by the vehicles. Coded identifier and location data is automatically transmitted to a central headquarters location where it may be processed and stored for deriving instructions which may be issued to drivers of individual vehicles by conventional broadcast communication equipment. The impulse transmitter and impulse receiver elements are of very simple nature and are otherwise inexpensive of installation maintenance, and operation, adapting readily to cooperative use with conventional transceiver equipment already in use in many types of fleet vehicles. The invention has great versatility, being adaptable to use, for example, with manual monitoring and manual map posting at headquarters, along with voice communication of instructions where the vehicle fleet to be monitored is small. On the other hand, the invention lends itself to use at headquarters with complex data processing equipment for performing one or more of the same or other functions in a multiple unit fleet. It will be apparent to those skilled in the art that the central processing equipment, including displays, may be generally similar to those employed in air line or rail road traffic control systems.

While the invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than of limitation and that changes within the
purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

We claim:

1. A vehicle monitoring system for signalling to a central station the presence of a cooperating vehicle at any one of a plurality of predetermined locations comprising:
   a plurality of independent electromagnetic impulse transmitter means for continuously illuminating said respective discrete predetermined locations, each said impulse transmitter means being characterized by transmitting signal impulses having a distinctive impulse repetition frequency for identifying its respective predetermined location, electromagnetic impulse receiver means aboard said cooperating vehicle for counting the number of said signal impulses received in a predetermined time interval, encoder means responsive to said electromagnetic impulse receiver means for forming an encoded representation of said number of said signal impulses received in a predetermined time, and vehicle borne transmitter means responsive to said encoder means for transmitting said encoded representation to said central station for identification thereof of said vehicle when illuminated by said electromagnetic impulses.

2. Apparatus as described in claim 1 including means cooperating with said vehicle borne transmitter means for transmitting representations to said central station for identification thereof of said vehicle.

3. Apparatus as described in claim 1 wherein said vehicle borne transmitter means further includes omnidirectional antenna means.

4. Apparatus as described in claim 1 wherein said electromagnetic impulse receiver means comprises: electromagnetic impulse receiver antenna means, biased diode means for converting said electromagnetic energy impulses collected by said receiver antenna means directly into amplified current impulses, and means for converting said amplified current impulses directly into output pulse signals having durations substantially longer than said amplified current impulses.

5. A communication system adapted for receiving impulse transmissions having a distinctive repetition frequency characterizing a particular vehicle location comprising:
   vehicle mounted omnidirectional antenna means for collecting said impulse transmissions when said vehicle is at said location, biased diode circuit means connected to said omnidirectional antenna means for converting said collected impulse transmissions directly into amplified current impulses,
   pulse shaping means connected to said diode circuit means for forming corresponding output pulse signals having durations substantially greater than said amplified current impulses, counter means for counting the number of said output pulse signals occurring in a predetermined time for identifying said location of said vehicle, and transmitter means responsive to said counter means for encoding the output of said counter means and for transmitting said encoded output of said counter means directly to a central station for identification thereof of said particular vehicle location.

6. Apparatus as described in claim 5 further including means cooperating with said transmitter means for transmitting representations to said central station for identification thereof of said vehicle.

7. Apparatus as described in claim 5 wherein said pulse shaping means connected to said biased diode circuit means for forming corresponding output pulse signals having durations substantially greater than said amplified current impulses is coupled in feedback relation to said biased diode circuit means for assuring extinction of current flow through said biased diode circuit means at a delayed time after the start of each amplified current pulse.

8. Apparatus as described in claim 7 wherein said counter means for counting the number of said output pulse signals occurring in a predetermined time comprises:
   a gate circuit having input, output, and control means, means for coupling said output pulse signals to said gate input means, interrogator control means coupled to said control means for causing said gate to conduct for a predetermined time period, and pulse counter means connected to said gate output means for counting said output pulse signals passed by said gate within said predetermined time.

9. Apparatus as described in claim 8 comprising:
   encoder means responsive to said counter means for generating an encoded representation of the number of said output pulse signals passed by said gate within said predetermined time, and omnidirectional radiating transceiver means responsive to said encoder means.

10. Apparatus as described in claim 5 wherein said biased diode circuit means comprises:
    bistable semiconductor diode means, circuit means for biasing said bistable semiconductor diode means substantially at the current conduction condition thereof, and means for coupling said impulses collected by said antenna means to said bistable semiconductor diode means for causing impulse current conduction thereof.