TECHNOLOGICAL ASPECTS OF PUBLIC RESPONSIBILITY FOR GRADE CROSSING PROTECTION

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Recent interest in improvement of safety at railroad-highway grade crossings has been accompanied by a growing involvement of government at all levels. Public responsibility typically has been confined to providing funding, developing information, planning, and regulating; the design, installation, and maintenance of automatic protection has been exclusively a railroad activity. This paper examines the technical limitations that constrain public authorities from taking total responsibility for crossing protection devices, which are the only highway traffic control devices that are not the responsibility of highway officials. Research directed toward removal of those limitations is described. A review of the legal history and current role of governmental units precedes a description of conventional technology in terms of impact on a wider public role. Means of train detection and motorist warnings are discussed; the conclusion drawn is that the principal technological impediment to non-railroad responsibility for crossing protection is the present dependence on track circuit techniques for determination of train presence. Recent research directed at removing this constraint is presented. Analysis of system requirements and available technology has identified a discrete train detector-microwave communication link concept, and the results of field testing indicate a number of attractive features and general feasibility.

•IN recent years there has been a significant increase in the attention directed toward improvement of safety at railroad-highway grade crossings. Examples of this awakening—particularly at all levels of government—include the Highway and Railroad Safety Acts of 1970 and the resulting two-part FRA-FHWA Report to Congress (1, 2); aggressive and comprehensive information-gathering and protection implementation programs in a number of states; formation of Department of Transportation and Highway Research Board committees; and convocation of four national conferences. Federal and state funding legislation, development of improved governmental structures, and an improved information base for policy formulation and implementation have been accompanied by steadily increasing assumption of both capital and maintenance costs by public bodies. In 1972 a new FHWA policy eliminated completely the requirement for any railroad contribution to the cost of installation of automatic protection on federal-aid projects. At least 17 states now have special crossing improvement funds, and 11 share to some degree in maintenance expense—100 percent under certain circumstances in one state.

This growth of public involvement might not seem noteworthy to the casual observer. The basic function of crossing protection is, after all, to alert the motorist to a possible hazard—a responsibility normally assumed by governmental bodies for virtually all other potential dangers on highways. However, historical, technical, and legal considerations have traditionally lodged the primary burden of protection on the railroads.

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The movement away from that arrangement has arisen from a number of factors, which include the great increase in highway traffic, the diminished role of railroads as the predominant transportation mode, the impediment to efficient implementation of protection programs caused by diffusion of functions among numerous public and private bodies, and the ever-greater degree to which public funds are involved.

It is the objective of this paper to explore the subject of direct involvement by public agencies in the actual installation and maintenance of automatic crossing protection, including the possibility of complete independence from the railroads. A description of the general background and context of grade crossing protection matters is followed by a review of relevant present technology and both the practical and inherent limitations thereby imposed. Attention is then given to the nature and benefits of activities that could be undertaken by governmental bodies either within conventional techniques or through application of recent technical developments. The latter discussion is based primarily on research carried out over the last 3 years concerning alternatives to track-circuits for actuation of motorist warnings.

BACKGROUND

The "grade crossing problem" began almost with the first railroad and became a significant concern as railroads expanded in the late 19th century. The legal history of the subject has been examined by FRA (1) and is only briefly summarized here. In the 1890s several court decisions held that assignment of the crossing protection responsibility to the railroads was both within the inherent police powers of the states (to ensure public safety) and justified as an obligation naturally associated with the railroad's acceptance of a franchise. Although this basic view prevailed until the 1930s, the dramatic increase of motor vehicle traffic and highway improvements soon raised the problem to a serious level, causing reconsideration. The early ventures into federal financing of highway construction permitted, in 1916, the use of such funds for reduction of hazards at railroad-highway crossings; usually a substantial railroad contribution was required. However, the primary responsibility for crossing protection quite clearly remained with the railroads. During the depression, financial difficulties for the railroads were accompanied by major federal-aid highway construction programs, creating many additional crossings on improved highways. This was an important change from the 19th century, when new tracks were generally cutting across existing highways.

At this time both governmental policy decisions and several landmark court cases established a marked turn toward increased public responsibility. At the federal level, the basic guideline to emerge from the 1930s (widely, but not universally, accepted) was that costs should be assessed in proportion to benefits received. One indication of the result is the observation that during the period from 1934 to 1972, for those crossing protection projects involving the use of federal funds, such monies comprised 83 percent of the total $3.5 billion expended. The next major turning point was the extensive study undertaken by the ICC in 1961 and concluded in 1964. An important finding was that "The cost of installing and maintaining such separations and protective devices is a public responsibility and should be financed with public funds the same as highway traffic devices" (3).

The acceptance of major federal responsibility was underscored in 1970 by passage of the Federal Railroad Safety Act, the Highway Safety Act, and the Federal-Aid Highway Act, all of which address grade crossing safety in a substantive way, and later by the Highway Safety Act of 1973, which provides for specific funding for automatic protection and funding (for the first time) for installations off the federal-aid system. Similarly, a number of states have undertaken coordinated and comprehensive programs in problem definition, policy formulation, and installation of protection and have established special state funds for both capital and maintenance costs.

Grade separations, being extremely expensive, have typically accounted for the major part of resources expended (94 percent in the period 1967-1970) and are generally motivated and justified more on grounds of motorist convenience and reduced delay than on safety, since nearly as great a level of protection is possible with automatic

devices at a fraction of the price. Indeed, a conclusion of the report to Congress (1, 2) is that the most effective and beneficial expenditure of available resources in terms of safety is a program of installation of new protection and improvement of that already existing at approximately 30,000 public crossings. Thus, it is this topic—implementation of active protection—that has generally received major attention and that forms the focus of this paper. Both conventional and innovative technology are considered, with special attention given to those aspects of particular relevance to public responsibility.

NATURE AND IMPLICATIONS OF CONVENTIONAL TECHNOLOGY

Discussion of grade crossing technology is facilitated by delineation of two quite separate functions: (a) detection of actual or imminent train presence at the crossing and (b) presentation of appropriate warnings to the motorist. It is sometimes useful to consider as separate the interface circuitry that connects the basic train detection equipment to the warnings. However, that function is often physically a part of the system that determines train presence and is so treated here. The basic principles of conventional techniques are easily stated, since practices are well standardized. During the fluctuations in funding and other responsibilities described earlier, one factor has remained constant: The railroads have always been responsible for design, installation, and maintenance of crossing protection. Thus, the hardware and concepts associated with automatic protection arise directly from railroad signal technology and practices and have been controlled exclusively through establishment of industry (AAR) standards, specifications, and requisites.

Train Detection

A brief review of the history and state of the art of such systems has been given elsewhere (4) and will not be repeated here. However, certain critical aspects deserve emphasis.

The most fundamental and universal characteristic of active protection is use of the track circuit for train detection. Invented for general railroad signal purposes in 1872, it forms the basis of block signal technology and was first applied to grade crossings in 1914. The basic concept is shown in Figure 1. The principle of operation is quite elegant. The battery at one end of a section of track—electrically isolated at both ends—is connected to a relay at the other end, using the rails as electrical conductors; the normally closed relay is held in an open position. A train between the battery and the relay short-circuits the relay, which, upon losing current, closes, thereby activating any desired warning, such as a bell, light, or gate. Several features are particularly noteworthy. Any open circuit (break) in the rails or connections, or any short circuit across the rails, or failure of the power source (battery) causes the gravity-operated relay to close, actuating the warnings. Thus, with respect to all primary failure modes, the system is fail-safe, in the sense that malfunction causes the most restrictive signal aspect—a fundamental criterion for all railroad signaling. Actual achievement of a protective system approximating truly fail-safe operation requires careful attention to many details, particularly in the more complex designs and installations now used. Many years of evolutionary improvement have been required to provide the high level of performance now available. Such a system, unless equipped with overriding devices, provides continuous detection, in that a train is detected constantly while in the block.

The most basic crossing protection system, then, entails a track circuit on either side of the crossing ("approach circuit"), with a third covering the region where the tracks actually cross the highway ("island circuit"). The length of the approach circuits must be sufficient to provide 20 to 30 seconds of warning for the fastest train speeds allowed—approximately ½ mile (0.8 km) for a 60-mph (97-kmph) train speed limit. Modern modified installations utilizing audio frequency signals rather than direct current, with solid-state logic, have proved advantageous in many locations, but a number of constraints to this approach remain. The track segments involved must have electrical integrity throughout their length and isolation at each end. A

substantial quantity of power is required at the "battery" end (whether DC, AC, or audio frequency)—at least several watts—and this must be provided via special cables or existing track-side power lines. In addition, all active elements must have emergency power—batteries—available in the event of power or fuse failures. The challenging nature of the railroad operating environment—weather, temperature extremes, vandalism—should need little elaboration, but it is appropriate to note the less obvious difficulties, such as vulnerability to lightning and other power surges and variation of the electrical impedance of the ballast between the rails.

In recent years, a new class of devices has been developed that also use the rails as conductors and detect the trains from the shunting effect of the train wheels and axles. However, there are significant differences and new functional capabilities, compared to the basic track circuit. The concept is shown in Figure 2 and is dependent on measurement at the crossing of the electrical impedance between the rails. Although the rails have a very low resistance, it is not zero, so that as a short circuit (a train, for example) moves toward the crossing the measured impedance decreases. Thus, it is possible to determine not only that the block is occupied but also whether the vehicle is moving and the direction of motion, toward or away from the crossing. In the simpler applications of this concept, such devices serve as motion detectors, eliminating unnecessary actuations when trains stop near a crossing or move away from it after stopping and reversing. The more sophisticated forms can actually measure range and closing rate with sufficient accuracy to activate warnings a fixed time interval prior to train arrival, regardless of train speed. This constant warning time feature appears to be highly desirable. In part, it reduces unnecessary motorist delay, but, more importantly, it also provides a far more precise, and thus more credible, warning, and motor vehicle operators appear more likely to obey signals that experience shows to be truthful. Such devices require power only at the crossing, with a passive termination at the end of the block, but the more complex version for constant warning time also demands substantial power—tens of watts.

In summary, the track circuit approach is well proved, effective, and reliable, but it is also relatively labor-intensive in both installation and maintenance and is therefore not inexpensive. Although largely fail-safe, system malfunction is generally not easily distinguished from train presence, which leads to an undesirably high false-alarm rate, with unfortunate impact on system credibility and motorist response. However, the most important weakness in terms of this discussion is the inherent inseparability of track circuits from railroad involvement and responsibility for operation. It is clear that this technique—as effective as it has proved for the railroads—is totally inappropriate to implementation by any non-railroad body. Thus, total public responsibility for crossing protection can be achieved (if desired) only through alternative technology, for which there has previously been no demand. This topic will be explored at a later point.

Motorist Warnings

Given a reliable and accurate means of train detection, the heart of the protective system is the means by which the train presence is displayed to the motorist. If it is to be effective, virtually all drivers must see the warnings, understand their meanings, and be motivated to act accordingly. The fact that nearly 40 percent of crossing fatalities occur at railroad-highway intersections that have some form of active protection suggests that this sequence fails all too often. Unfortunately, the statistical data are inadequate at present to identify specific weaknesses. "Active protection" as used here includes a wide variety of hardware and crossings, and it may well be that the best of present-day systems, properly installed and maintained, can demonstrate a far better record than the average for all active protection. Indeed, figures reported by the California PUC (5) suggest very high effectiveness for well-engineered gate installations, which generally include constant-warning-time train detection. It is noteworthy that California, in strongly emphasizing gates, reduced crossing accidents by 49 percent from 1965 to 1972, while the remainder of the nation showed only a 7 percent decline (6).

Figure 1. Basic track circuit.

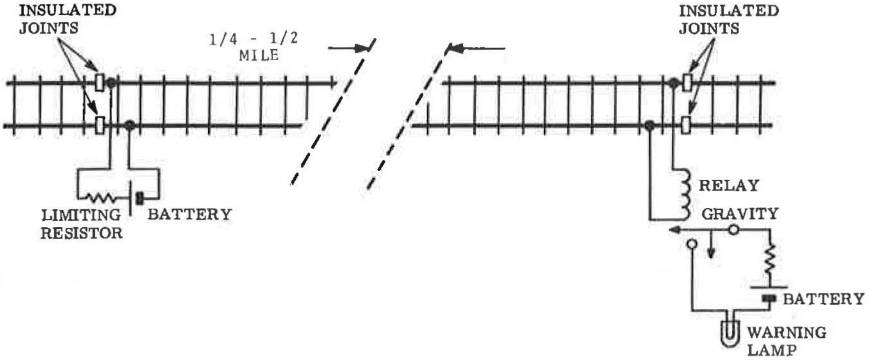

Figure 2. Basic impedance-measurement train-motion detector.

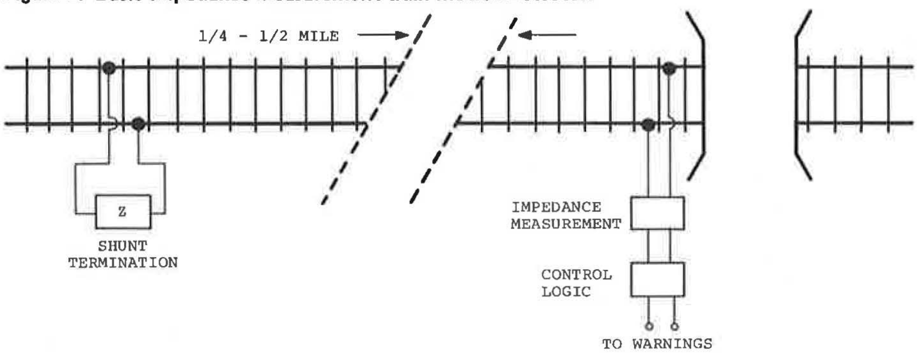

Figure 3. Basic telemetry system.

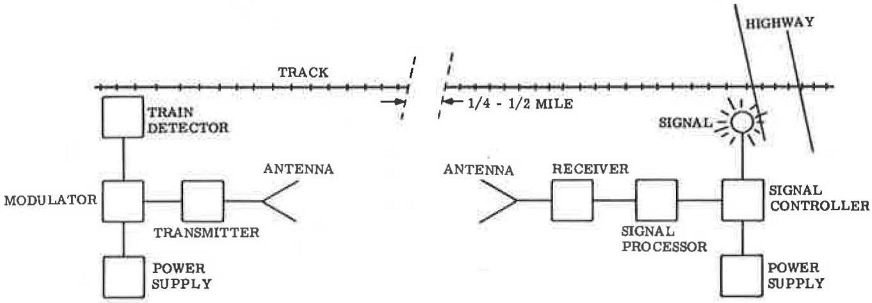

Figure 4. Telemetry system during field test (transmitter location, solar panel in use).

Regardless of statistics, an informed observer may question whether present active warnings represent the best that can be achieved. Although many variations exist, the two basic devices used throughout the United States are flashing lights or flashing lights plus automatic gates. The lights, which are used alone at 80 percent of crossings with automatic protection, have been developed by the railroad signal community rather than highway signing engineers and scientists, and this has led to certain characteristics. The flash rate (35 to 40 cycles per minute) is modeled after the rate at which a man customarily swings a lantern. The shade of red commonly used is substantially deeper than general highway use demands, determined in part by the basic railroad concern that an engineer might mistake a red block signal for amber. This was unfortunate, since light intensity was reduced more than necessary by the dark lens. Some recent installations of flashing lights have used a lighter red such as the ITE shade, although further improvement is possible. Intensity is a serious concern with grade crossing flashing lights, since the requirement for a 1- to 3-day back-up battery power supply dictates minimal power consumption. The bulbs have generally been 11 or 18 watts; 25-watt units are now coming into use. Sufficient brightness is obtained through utilization of narrow-beam focusing lenses and high-quality reflectors. This requires precise alignment, achieved only through frequent maintenance and very sturdy (and expensive) mounting structures, which are quite impressive in size when lights are mounted over the highway on cantilevers.

Criticism of these devices is not the point of this discussion. However, it is not unreasonable to examine alternatives with the goal of beneficial impact on both cost and effectiveness. There are no serious technical barriers to such experimentation, either by railroads or public bodies. (Many years of dealing with the problems of interconnecting crossing protection signals and nearby highway traffic lights have established procedures by which railroad-owned train detection systems can be used to operate non-railroad devices with no danger of creating malfunctions for which the railroad is not responsible.) The principal difficulties in this area are legal and institutional. Railroad companies are bound both by strong concerns for liability—"experimental" devices may be ill-received by a jury—and by standards established by trade organizations and state regulatory bodies. Public authorities appear to have been loath to attempt to complicate further the task of achieving installation at a particular crossing by seeking some new, non-standard warning. In addition, these constraints have served to limit interest by others in development of improved, innovative devices.

This situation is unfortunate, for it not only prevents innovation in general but also has tended to exclude those most knowledgeable in the subject of motorist warnings from involvement in this key element in crossing protection. (For example, the Manual on Uniform Traffic Control Devices merely refers to Association of American Railroads standards.) However, as noted, the situation is not without hope; alternatives can be tried if the railroad and the state are willing. Experimental systems can be in addition to standard equipment if suitable, although regulatory waivers and liability insurance may be required. The point to be emphasized is that it is physically possible for public authorities (most probably highway departments) to install and maintain innovative (or conventional) warnings, and in many cases this may be feasible—if not easy—within the institutional constraints as well. A current example of such an effort is the installation of strobe lights on gates on a high-speed rural highway carried out by the State of Indiana and the Norfolk and Western Railroad.

Advance Warnings

In the case of advance warnings—those installed before the crossing merely to alert the motorist to the impending potential hazard—much greater freedom exists, although it has been little utilized. In addition to a less rigid relationship to liability and regulatory aspects, such warnings are in most cases already the responsibility of highway authorities. This aspect of crossing protection has generally received very limited attention, although recent state and FHWA research projects auger well for improvement. The present standard warning has a limited ability to attract attention,

particularly if poorly maintained, and provides only the barest information concerning the imminent hazard. The motorist is not told whether the protection provided is active or passive, although his surveillance activities should be dependent on this. The number of tracks, angle of the crossing, possibility of obscured sight lines, and nature of the rail traffic are all ignored. Such information could, of course, be readily provided.

The subject of active advance warnings is particularly interesting. Given the major investment associated with automatic protection, it is clearly desirable to maximize the effectiveness obtained. As mentioned in connection with crossing-located motorist warnings, there is no major technical problem involved in obtaining train presence information from railroad-operated train detection apparatus and using it to activate advance warning devices. In special situations, particularly those characterized by blind approaches, both states and railroads have used such devices. However, more widespread application could carry significant benefits, and implementation poses no major problems other than the ever-present question of availability of funds. It should be noted also that new active warning devices can be tested first as advance warnings and then be considered for installation at the crossing if found to be effective.

In summary, current technology and practices are such that only standard passive advance warnings are the responsibility of public officials. The basic concept underlying conventional train detection—the track circuit—virtually excludes non-railroad operation of that element of the system. However, the possibility of more extensive public concern with active, crossing-located warning devices appears to be limited more by tradition and legal and institutional factors than by technology and offers the opportunity for greater experimentation than has been the case to date. Improvement of advance warnings, particularly through the use of active devices, has received attention in some states but appears to remain a promising area for substantial public involvement, in terms of both ease of entry and potential benefits.

RELEVANCE OF TECHNOLOGICAL INNOVATION TO PUBLIC INVOLVEMENT

The foregoing discussion has shown that the primary technical limitation on full public ownership and operation of grade crossing protection is associated with the task of timely actuation of motorist warnings. Although trains do indeed make their presence known in a wide variety of ways, the demands made on crossing protection systems are severe and not easily met. First and foremost, all trains must be detected adequately in advance of arrival—typically 20 to 30 seconds. All system failures must result either in activation of warnings or unmistakable indication of the malfunction. The operating environment is severe, and both practicality and safety demand extremely durable equipment with a long service life and limited maintenance needs. Costs must not be extreme—certainly no greater than for conventional equipment.

Low power consumption is desirable in general to reduce the required investment and maintenance associated with an emergency supply and is particularly important away from the crossing, where provision for line power can add significant expense and vulnerability to lightning damage. Power drain of less than ½ watt is desirable. Finally, for total public responsibility, there must be a high independence of railroad property and systems. Of the many alternative techniques that might be considered, most can quickly be rejected through application of the above criteria. Several, which have been found to merit further consideration, are discussed in the following sections.

Train Presence Detectors

Most potential alternatives to track circuits explictly separate the train detection and communication functions. This approach involves specifically checking trains in and out of critical regions rather than noting presence continually, as do track circuits. One then requires specific detectors of train presence at a particular point. Rail vehicle presence detectors are used in a variety of applications, generally not vital (safety-related), and several types exist. Other concepts, some drawn from related fields, could be developed for the grade crossing case. The "perfect" sensor, which probably

does not exist, would be characterized by very low (or zero) power consumption; fail-safe operation; no electrical or mechanical attachment to the rails; high resistance to weather and vandalism; indication of train direction and velocity; sensing of stationary trains; and low cost. A brief review of the state of the art follows.

Wheel Detectors—The most common type of detector in general railroad use is the wheel detector, which bolts to a rail and detects passing wheel flanges either magnetically or inductively. Both active and passive methodologies are available; active devices consume significant power but offer better possibilities for fail-safe operation. Such devices are subject to damage by dragging equipment, plows, and vandals, and prices range from approximately $200 to $800. Physical connection to the rail implies railroad involvement, but there is no inherent link to the signal system, nor dependence on electrical characteristics of the rails. Speed and direction measurement is possible at significant increases in cost and power.

Inductive Loops—A commonly used highway vehicle detector is the inductive loop, which is also produced in a form suitable for railroad use. Relatively high power consumption is a weakness. They must be installed in close proximity to the tracks, over a relatively large area, so that cost, durability, and vandal resistance can suffer. Velocity and direction information are not easily obtained.

Magnetometers—Since all rail vehicles are composed partly of large masses of iron (for example, the wheels), magnetic detection is natural to consider. A commercial traffic detection magnetometer was tested, buried 1 ft (30 cm) below the track level. Results were highly satisfactory, although power consumption was higher than desired. Multiple units are required for velocity and direction discrimination, doubling cost and power consumption.

Beam Interruption—A common means of detection of moving objects is interruption of a beam, typically of visible or infrared light. Difficulties associated with fog, dirt, and malicious activation appear solvable for this application with careful design, but power consumption, cost, and multiple-track situations all represent complicating problems. Speed and direction can be determined from dual-beam systems with moderately increased complexity.

Pressure—A natural possibility is detection of rail flexing or other pressure related effects. However, no obvious realizations or available devices that meet the criteria have been identified.

Mechanical—A rail-mounted treadle switch, activated by the wheel flange and used widely in Europe for other applications, was tested. However, unsafe failure modes, vulnerability to accidental and malicious damage, and maintenance needs make it an unpromising approach.

Sonar—Ultrasonic sonar, mounted above roadways, has been used successfully for vehicle detection. However, cost, vulnerability to weather (ice in particular), and high power consumption are substantial drawbacks.

Radar—Short-range radar, using compact antennas and solid-state oscillators, appears promising, although achievement of fail-safe operation is challenging. Complete independence from rail operation is possible.

In summary, there are a number of potentially feasible means of presence detection, each with certain strengths and weaknesses. Although no ideal detector is available, it appears that a satisfactory compromise is possible in most cases. The choice will depend on the relative importance of particular constraints—speed information, power consumption, railroad independence, etc.

Communication of Train Presence Information to the Crossing

The communication task may be simply defined. The basic requirement is transmission of information, at a very low data rate, over a distance typically less than 3,000 ft (914 m). The constraints described earlier must be met. One can easily imagine a number of possible approaches, but most have serious limitations. For example, the cost of underground or pole-mounted cable, including installation and maintenance, is quite expensive. Of the electromagnetic approaches, optical devices are too vulnerable to the environment for the range considered—dust, snow, mud, fog,

ice, and vegetation could all drastically interfere with proper operation.

On the other hand, radio techniques are quite suitable. Radio communications can be carried out using readily available apparatus in the frequency range of fractions to tens of thousands of megahertz. Efficiency, reduction of electromagnetic interference problems, and low vulnerability to extraneous signals strongly suggest the desirability of a focused, line-of-sight system in which signals are either absorbed by obstacles or pass through the ionosphere with no reflection. High frequencies are also desirable in that wider, less crowded bands are available and antenna size—determined by wavelength—can be smaller and thus more convenient. An important weakness of low frequencies (below 1 GHz) is the lack of durable, small, highly directional antennas; use of a narrow beam can increase system efficiency by a factor of 10^3 to 10^6 with both transmission and reception are considered. Economical microwave sources and compact, highly directional antennas are best obtained in the frequency range of 10 to 20 GHz. Significantly higher frequencies (above 30 GHz) would increase cost substantially, as both oscillators and other components would require closer manufacturing tolerances. In addition, above 30 GHz, attenuation from heavy rainfall can have a significant effect on propagation distances. On the other hand, at 10 GHz no severe problems occur for rainfall of less than 5 to 10 in. (12 to 25 cm) per hour, a rate at which motor vehicle traffic would presumably be at a standstill.

Considerations of this type lead to the conclusion that the most practical means of realizing the communication function is in the form of a simple microwave telemetry link, in which the short range and low information rate required make possible a simple, highly reliable, low-cost system. A basic communication link has been designed according to these guidelines, constructed, and tested in order to explore the feasibility of such an approach. A block diagram of the system is shown in Figure 3. Technical details of the effort are available elsewhere (7, 8) and are merely summarized here. A solid-state microwave transmitter, operating at 10.5 GHz, is placed at the downtrack train detection point, with a receiver at the crossing. The normal (train absent) condition is with the transmitter on, with pulse modulation of low enough duty cycle to provide minimal power consumption. At the receiver, this signal is detected and rectified, giving an output voltage as long as a signal is received. In the absence of such a signal, for whatever reason, there will be no output, and malfunction or motorist warnings are activated to provide fail-safe operation. It is highly desirable that there be a detectable difference between system failure and train presence, so the latter case is indicated by a change in the modulation waveform rather than total absence of signal. The receiver also has an input from a train detector at the crossing, so that it is reset to the train-absent state after a train moves across the crossing. As is the case for track circuits, appropriate logic is necessary to account properly for train presence, direction, etc., particularly in multiple-track situations.

Pulses are transmitted at a rate of 2 to 3 per second, so the system responds to train presence in approximately 1 second. The power consumption of the transmitter is approximately 100 mW, or 1 kW-h per year, and this can be reduced still further. Charging from solar panels 1 ft^2 (930 cm^2) in area is entirely feasible and not excessively expensive. Use of sealed batteries can reduce periodic maintenance needs to annual servicing. An installed prototype system, utilizing solar panels, is shown in Figure 4. Six such installations, in several variations, have undergone extended field testing under realistic conditions of operation over periods of 6 to ten months. The tests were carried out at grade crossings with conventional active protection in place. Both the existing track circuits and the experimental units activated strip-chart event recorders, providing a clear indication of the reliability and accuracy of the new systems. A variety of train detectors was used, with primary reliance on magnetic flange detectors and magnetometers. The sites were located on Boston and Maine Railroad mainline track within 25 miles (40 km) of Boston.

Results of the field tests were highly encouraging and clearly demonstrate basic feasibility. Difficulties that occurred are typical of first-stage field testing of prototypes and generally involved peripheral hardware. The basic system concept has proved completely satisfactory. The transmitter and receiver have sufficient margin that performance can be degraded very markedly—over 20 db—before malfunction

occurs, and this will be in a fail-safe mode, with a malfunction indication generated.

The cost associated with this approach is clearly a very important factor in ultimate viability. The exploratory nature of this work prevents quotation of exact prices. However, the basic circuitry is of approximately the same complexity as found for track circuit systems, and it appears that installation and maintenance requirements can be significantly reduced. Expenses associated with provision of power and surge protection should be lower, and in multiple-track situations one telemetry system, with additional sensors and logic, can replace several track circuits. Thus it appears that cost reductions of 20 to 30 percent are realizable, although the principal benefit of this approach is felt to lie with the potential it offers for public operation of crossing protection.

CONCLUSIONS

In terms of both technical and legal considerations, public authority for crossing protection is most readily assumed in operation of active advance warnings, acting to supplement existing crossing-located railroad equipment. Simple means of actuation are possible that allow complete isolation from railroad circuits. This area has been addressed in several states and locations but appears to warrant greater attention. There is less risk in experimentation with advance warnings, so that trials of new types of signals are not so severely constrained. Devices that show high effectiveness then become candidates for installation at crossings.

The technical constraints on public responsibility for active warnings—but not train detection—at the crossing are no greater, but legal questions present an obstacle. In the event of any failure, there is a possibility of extended controversy over whether it occurred in the detection system or the warning devices. Railroads might naturally hesitate to enter into such an arrangement for fear of becoming embroiled in the failures of another party. Relevant standards of regulatory bodies might also require waiver. Matters could be facilitated through purchase of liability insurance; such a strategy is uncommon but not unknown.

Full public responsibility for the total protection system, including train detection, poses a severe technical problem at present, since conventional technology in this country is universally based on track circuit techniques. Research at the Transportation Systems Center has demonstrated the feasibility of a non-track-circuit concept, although significant product development, field testing, and refinement are necessary before such a system would be acceptable. Also, there is an additional practical constraint on implementation. Such systems appear to offer significant cost savings, but that estimate is based on production volume comparable to that for conventional hardware. However, railroads are naturally reluctant to introduce a system totally unrelated to present techniques, since this complicates inventory and labor matters. Thus, reasonable production—and attractive costs—are likely only if a number of states and localities actively choose to follow such a course.

A decision of that nature will not be easy. The advantages of simplified implementation of crossing protection—lower cost and more direct control—are offset by the need to establish the appropriate facilities and labor force and (perhaps more restricting) to face the potential lawsuits in the event of accidents. Liability is not the subject of this paper and will not be addressed here, but it appears that the overall legal constraints and responsibilities involved cannot be completely spelled out in advance but rather will evolve as various precedents are applied to a succession of cases. There appear to be major benefits associated with a decision to accept this challenge—improved protection and enhanced capability to implement a comprehensive, coordinated program—and history shows a steadily increasing public involvement that may ultimately include total responsibility.

A first significant step could be taken if a state or other public authority assumed responsibility for installation, operation, and maintenance of some active motorist warning devices at the crossing, with the railroad continuing its traditional responsibility for the train detection track circuits, terminating them in a junction box in the vicinity of the crossing in which the state would make connections leading to the warning devices.

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