DEPARTMENT OF CIVIL ENGINEERING
BRIGHAM YOUNG UNIVERSITY

ROADSIDE-TO-VEHICLE COMMUNICATIONS

By

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ROADSIDE-TO-VEHICLE COMMUNICATIONS

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In Partial Fulfillment
of the Requirements for the Degree of
Master of Civil Engineering

by
Gary Jim Xanthos
August 1972
This project, by Gary Jim Xanthos, is accepted in its present form by the Department of Civil Engineering Science of Brigham Young University as satisfying in part the requirements for the degree of Master of Civil Engineering.

Arnold Wilson, Committee Chairman

Dean K. Fuhriman, Committee Member

June 2, 1972
Date

D. Allan Firmage, Department Chairman
ACKNOWLEDGEMENTS

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ROADSIDE-TO-VEHICLE COMMUNICATIONS

INTRODUCTION

"Danger! - Slow Down!" the car radio blares out as you rapidly approach a roadside hazard. You react, slow down, and avoid trouble. Thanking the rabbit's foot hanging down from the rear view mirror you proceed on just vaguely aware of the value of the roadside-to-vehicle communication unit you just interacted with.

What is this system? What does it do? How does it work? Does it exist, and if so, can it be shown to be economically feasible? These questions and others express the basis for this research project entitled Roadside-to-Vehicle Communications.

In this project the author is trying to promote the installation of a roadside-to-vehicle communication network system which shows great promise of significantly reducing highway accidents. In order to do this, a three "pronged" approach is used. First, a simple system is proposed which can be installed almost immediately at low cost, will help reduce accidents and will help pave the way for more effective communication network systems.

The second approach will alert the reader to roadside-to-vehicle work done by General Motors Corporation, the Ford Motor Company, and others. Hopefully this will inform the reader of what
has been done, and will motivate him to seek further information. Armed with such information he will then be in a better position to help implement an effective roadside-to-vehicle communication system.

The third approach is to leave the reader with some different communication system ideas in order that he might find areas of research not yet tried. Applications presented in the third approach might be practical sometime in the future.

The philosophy behind the whole report is, the sooner we act to reduce highway accidents, the better.

This report is based first, on library research of actual roadside-to-vehicle communication systems tested by others, and second, on actual experimentation of the proposed communication system undertaken by Malcolm D. Crawford, Arnold Wilson, and Gary J. Xanthos.
CHAPTER I

A ROADSIDE-TO-VEHICLE COMMUNICATION
SYSTEM PROPOSAL

Are you, the reader, aware that over 50,000 people are killed each year on the streets and highway system for a total annual economic loss of more than 10 billion dollars, or an average of one cent per vehicle mile (excluding loss due to nonfatal and minor injuries)?

The statistics show that for Utah, in 1955, the direct costs of passenger car accidents was 23 million dollars (1). If these statistics concern you and you are interested in a proposal that will help reduce such future accidents, then consider the following proposal for an "Audio Sign" system presented in this chapter of this report.

System Layout

The system being proposed is extremely simple (see Figure 1). It consists of the following:

1. A low power (50 milli watt) radio transmitter.
2. A cassette recorder and tape loop.
3. A dipole antenna which consists of two lengths of any insul-
FIG. 1 - Simple roadside-to-vehicle communication system.
ated wire. This wire runs on or under the ground in either
direction parallel to the roadway and connects into the transmitter.

4. A sign which directs the motorist to tune his radio
receiver to a particular frequency. Such a sign will be needed only
temporarily and may possibly be omitted altogether, as will be
explained later.

5. A standard AM car radio.

A message such as "stop," "slow down," "danger ahead,"
"work crews ahead - please exercise extreme caution," etc., is
recorded on a tape loop of a few inches length. The message is
repeated as the tape loop continuously circulates underneath the tape
head. If desired, up to four tracks, and thus up to four messages,
can be placed on the tape loop. The tape recorder is connected into
a very simple transmitter which sends out the message along the
antenna on an AM wavelength. The radio waves are effective only on
the roadway close to the antenna, and thus radio interference is held
to a minimum. The radio waves are received by the regular car
radio in the same manner that regular standard station radio waves
are received.

Economic Feasibility

Let's be brief--Assume that the system eliminates one
accident from Table 4-8, listed in "Direct Costs of Highway Accidents
in Massachusetts and Utah"(1:80). We find that in Utah, in 1958, the

* Number in parenthesis refers to references listed on page 27.
costs for accidents were as follows:

<table>
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<th>Severity of accident</th>
<th>Dollars per accident</th>
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<tr>
<td>Fatal injury</td>
<td>$3,690</td>
</tr>
<tr>
<td>Nonfatal injury</td>
<td>1,277</td>
</tr>
<tr>
<td>Property damage only</td>
<td>299</td>
</tr>
<tr>
<td>Average of all accidents</td>
<td>491</td>
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Given an accident in Utah during this year, we can expect to lose $491. Therefore, we can afford $491 for a system which will prevent such an accident. The estimated cost of the system is as follows:

- Low power radio transmitter
  (Can be mass produced for under $5.00) $  5.00
- Cassette tape recorder and tape loop 40.00
- Wire 5.00
- Installation time
  (Of man-day equivalent) 40.00
- Car adjustments 0.00

Total estimated cost $90.00

In short, excluding the social costs, for the cost of one avoided accident the public can afford to install at least five such audio signs. Such a high rate of return of an investment is further increased when more than one accident is prevented. Furthermore, how much would you be willing to pay for a system that might have prevented an accident and injury that happened or could happen to you? The value of such a system might approach infinity.
A further advantage lies in the fact that in the near future, for about $25.00 or less, a modification to the car radio can be made to allow it to receive a particular frequency at all times. Such a device would automatically activate the entertainment radio to the message frequency for the duration of the message. It would then return the radio receiver to the condition it was before the message was activated. Such a system would add little to the basic cost of the system, but would make the audio sign system more flexible and would thus increase the effectiveness of the system. Another future modification to the system would allow messages to be sent from a central location to any specific audio sign. This could be done either through telephone lines or by radio communication channels. Figure 2 (3) illustrates a possible use of such a modified system.

Experimental Results

The system was assembled and set up by Malcolm Crawford of the Electrical Engineering Department of the Brigham Young University. The site selected for the experiment was a road located in Provo, Utah. The audio sign was set up in less than fifteen minutes, the car radio was tuned to the correct frequency and then was driven around the area. As the car approached the near end of the wire, the message was heard. While the car was between the two ends of the antenna the volume of the message was a maximum. The volume of the message quickly faded as the car passed the far end of the system.
FIG. 2 - Audio sign system installation.

Drivers can be warned of unseen road obstacles, slides, etc. The portable system can be set up by a highway personnel several miles ahead of the trouble area directing the motorists to a suitable bypass.
The demonstration proved its purpose by showing that the simple and economical system works. The next step is to put the system into beneficial use. The author of this report realizes that more complex systems exist and do much more than the audio sign system proposed. However, it has been, and will probably yet be a long time before these systems will be put to practical use.

What is needed now is a system which is economical, can easily be incorporated into the highway system, and will potentially save money and lives. This system should also be flexible to improvements in the near future which will greatly improve the system's effectiveness. Finally, the system should act as a catalyst to motivate the developing and manufacturing of improved roadside-to-vehicle communication systems which will still further aid and help protect the driver.

The author feels the proposed system meets the requirements and should therefore be seriously considered.
CHAPTER II

OTHER ROADSIDE-TO-VEHICLE COMMUNICATION SYSTEMS TESTED

Some rather intensive roadside-to-vehicle communication system experiments have been undertaken. It seems that most such experiments to date are in conjunction with General Motors Corporation. The second best source of such current information comes from tests done under the Ford Motor Company. It is gratifying to note that these two corporations, plus some individuals, are interested in and doing something to improve highway safety.

The following section of this research paper is a compilation of work done by others on roadside-to-vehicle communication systems.

Vehicular communications started in 1921 with experimental radio telegraph installations.

It wasn't until the late 1950's that the idea of roadside-to-vehicle communication system experiments was really exploited. At this time articles from the General Motors Research Laboratories were published. One written by C. E. Quinn is introduced as "New Voice System Alerts Drivers" (3). In this article, C. E. Quinn describes a system that consists of the following:

1. **Transmitter.** The transmitter shown in Figure 3
functions as a double sideband, amplitude-modulated transmitter operating at a center frequency of 9 kcps. A highly intelligible message with minimal spectrum band width and transmitted power is maintained by a modulating frequency band width confined to the range from 400 cps to 1200 cps (1). A microphone and a tape recorder unit is used for message changes and "on the spot" traffic control. Power for the transmitter can be provided either from standard 60 cps utility power lines, from storage batteries, or both.

2. **Receiver.** The receiver works in conjunction with the car radio. This tuner type receiver which is fixed to a certain (hopefully standardized frequency) is as shown in Figure 4. The message control circuit is the only departure from standard radio design practice. This control circuit activates the car radio if the radio is on or off. Thus, the message can be clearly heard at all times. This control circuit also keeps ignition and other noises from being heard when the automobile isn't within the signal loop.

Advantages to this system are as follows:

1. The efficiency of this system doesn't wane in darkness or bad weather.

2. The system will reduce the chance of missing a road sign.

3. The signal pattern is controllable.

4. Interference to other services from harmonics or skip is nonexistant.
FIG. 3 - General Motors Highway Information System Transmitter.

FIG. 4 - General Motors Highway Information System Receiver.
5. The width of four traffic lanes will be covered from one side of the road.

6. Messages of high intelligibility (500 to 1500) cps are conveyed.

7. Other vehicles or road reinforcement don't attenuate radiation from the system.

8. 300 to 500 feet along the road is covered which allows messages of 3 to 4 seconds at speeds up to 70 mph to be handled.

9. Old messages are easily replaced in the repeater.

10. The receiver can be muted when no message is being received.

11. The transmitter is portable and easily installed for temporary service.

12. The receiver has a low standby battery drain for continuous use while driving.

13. The system is unidirectional in that only cars going one way receive the message.

Another article written for General Motors Corporation by E. A. Hanysz (2) describes a very similar roadside to vehicle communication system known as Hy-Com. In this article, the author specifically itemizes requirements for the tape message repeater unit. These requirements are as follows: (1) Easy-to-change message; (2) 0.8 mil. pickup-to-tape spacing; (3) Solid gear coupling between
motor and recording; (4) Temperature range of operations - 20° F to
120° F; (5) Power required: 12 volts d. c.; and (6) Low current drain
(200 ma).

In the latter 1960's other vehicular communication system
articles appeared. One article describes Ford Motor Company's
development of the Ford Radio Road Alert system of roadside-to-
vehicle communications (5). The phase of this system which cor-
relates with this report is entitled audio signs. Such a system cor-
relates with the system proposed in this report. A visual sign is
placed along the highway instructing the driver to set his transceiver
to a certain channel. The driver is then automatically informed of
conditions ahead.

Advantages are:

1. The message memory assures that the motorist will first
hear the "sign" at the beginning.

2. There is a provision for a critical piece of information to
supersede a lesser priority message. Thus, more than one channel
could be selected with no interference with critical messages.

3. The pick-up head doesn't make contact with the oxrite
century on the tape. Thus long tape life is insured.

4. The message will be heard at a preset volume whether
the car entertainment radio is turned on or off.

Disadvantages are:
1. It is relatively impractical at present since all vehicles need a special piece of equipment or a message memory system (presently located in the automobile trunk) which is electrically coupled to the entertainment radio.

2. Also, CB communications equipment is required.

The vehicle goes into future applications of the roadside-to-vehicle communications systems which are now in their infancy, as well as steps necessary to incorporate the communication system into widespread use on the nation's highways.

Another article published in the latter 1960's explains the DAIR Highway Communication System developed by the General Motors Corporation (4).

DAIR is an acronym for Driver and Information and Routing. One of this system's basic functions correspond with the system proposed in this article. Specifically, it is an Audio Sign which provides for the reception in the vehicle of voice messages pertaining to traffic conditions and emergency situations on the road ahead.

The Audio Sign function replaces the formerly described GMR system called "Highway Informer" and later called "Hy-Com". This function overcomes the considerable road power and the special single purpose receiver and antenna required in the former system.

The roadside equipment consists of the following: (1) a low powered high frequency transmitter, (2) a message repeater to modulate
the transmitter, (3) remote message lines and controls for changing to emergency transmissions, (4) power lines and batteries for power, and (5) magnet traps in the pavement upstream of the transmitter to activate the in-vehicle receiver speaker automatically.

The in-vehicle equipment consists of the following: (1) a C.B. receiver in the car to receive the message, (2) a "Mode Selector" to switch the system onto the right channel, (3) a magnet sensor mounted beneath the car to receive the coded impulse as the automobile passes over the magnetic trap, (4) a "Sign Minder" to decode the received impulses, and (5) a standard car radio.

This system, which in the experimental stage holds great promise for the future, still seems to fail to adequately meet the present criteria needed for a practical nation-wide roadside-to-vehicle communication system.

An article entitled "Study of the Feasibility of Using Roadside Radio Communications for Traffic Control and Driver Information" (6) reports of an investigation of the feasibility of roadside radio communication as a device to control traffic and inform motorists.

This project undertaken by Ronald O. Covault and Robert W. Bowes consisted first, of measurements of behavior of test vehicles in the traffic stream and second, of vehicle operator's answers to a public opinion-type questionnaire. The details of this feasibility study are presented in this article which is also included in this report.
Some conclusions formulated by Covault and Bowes are quoted as follows:

1. The messages received by the test vehicle operators did have a significant effect on the speed of their vehicles when compared to that of control vehicles who didn't receive the messages.

2. The radio system, even though in experimental stages of development, was not noticeably annoying to the driver.

3. Of the 1,616 interviews, 228 were considered biased and rejected. Of those rejected, equipment malfunction accounted for 197.

4. Ninety percent of the unbiased interviews indicated the broadcast messages were adequately or easily understood.

5. Most of the difficulty in understanding was caused by messages that were not clear or garbled in reception.

6. Messages helped in making the test vehicle operators feel safer, more alert, and contributed to a smoother operation of the vehicle through the test section.

7. Almost every interviewed driver thought that roadside radio communications in addition to standard signs were better than signs alone in most situations where it was necessary to give information or to caution drivers. The respondents also indicated that radio communications could be used effectively in situations where ordinarily no signing is used, such as in the vicinity of an accident.

8. It was almost the unanimous opinion of the interviewed drivers that roadside radio communication is a useful device in aiding the driver during inclement weather conditions.

9. More than 95 percent of the drivers favored the use of roadside radio communications in the vicinity of complex interchanges, traffic congested areas and detours. The use of the radio system to give information related to scenic and historic areas as well as service areas was acceptable to more than 70 percent of the drivers.

10. Most drivers would like to see this roadside radio communications system used on all major State highways.

11. Based on willingness-to-pay, most drivers indicated that the radio system had potentials. In response to the cost question, more than 25 percent of the operators were willing to pay in excess of $50 for an installation; 48 percent indicated that they
would be willing to invest more than $30 for an installation; and only 8 percent of those vehicle operators interviewed indicated that they would not purchase such a system. In analyzing the willingness-to-pay for the various groupings of the data, it was found that no significant difference existed in the amounts that males and females or local and nonlocal drivers were willing to pay. (6)
CHAPTER III

OTHER POSSIBLE METHODS OF ROADSIDE-TO-VEHICLE COMMUNICATION

The roadside-to-vehicle communication system explained in Chapters I and II are by far the most practical ones for the immediate future as well as those now promising the greatest long term benefits. However, these are perhaps not the only types of systems that can be used. Such possibilities, though lacking in practicality, are nevertheless interesting and are the ideas and basis that started the author's thinking and led his search to the proposed roadside-to-vehicle communication system. Possibilities will be discussed presently.

Wheel Rolling Over Transverse Cuts

When riding over rough road one notices a different sound than when traveling over a smooth surface. If the roughness was somewhat controlled then perhaps some predictions in the sound that the automobile occupants would hear could be made. Further, if the effects of well controlled road roughness, tire characteristics and sound transmission characteristics of the automobile were precisely known then there is a possibility that these mentioned factors could be controlled well enough to enable the car occupant to actually listen to
meaningful sounds as they drive over certain pavement sections.

The basic idea behind this system is to precisely space transverse saw cuts in the pavement. Then as the automobile travels across these saw cuts the reaction between the tire, shocks, auto frame, special equipment in the car, etc., and the pavement will cause sound waves to form which will be heard as words or phrases. The voice wave form can be simulated on a computer. From vehicle velocity one can find the spacing of the transverse saw cuts necessary to produce the desired sound. However, there would be interference from two sets of tires. (A simple diagram of transverse cuts is shown in Figure 5.)

Little experimentation along this line has been done. A few states have done a little experimenting with transverse saw cuts in an attempt to study a reduction in planning on wet roads. Florida in particular went a little further. The Florida Department of Transportation experimented with transverse saw cuts for the specific purpose of producing a noise or rumble effect to warn motorists of changing traffic conditions (see Appendix). The saw cuts were placed at a limited number of locations and the results were noted. Unfortunately (as will be explained later), the results of the experimentation were entirely negative.

There are many problems which presently preclude any feasibility of the wheel rolling over transverse plane cuts method of
FIG. 5 - Transverse saw cuts in highway pavement.

FIG. 6 - Longitudinal "Record" saw cuts in highway pavement.
road-to-vehicle communications. Some of the more obvious problems are as follows:

1. Using Bessel functions you can calculate frequencies for discs or maybe even rings as they roll along a plane surface, but when you start trying to calculate frequencies for rubber tires (especially with tread) rolling along irregular surfaces, the math soon becomes impossibly difficult because of the multitudes of frequencies involved.

2. Transverse saw cuts wear out fast so that the high order of precision necessary for good results would be very short lived.

3. Since required groove spacing and tires, etc. can't be determined mathematically, an unbelievably large number of costly experimental units would have to be tested on a trial and error basis.

4. Tests done on transverse cuts in Florida revealed that the noise level produced by their experiments wasn't high enough to alert the driver. Such tests showed noise levels barely discernible over other road noises with the car windows rolled down and unnoticeable with the windows rolled up. Thus special, and probably costly, amplifying equipment would have to be installed on all cars in order to give the system a chance to work.

5. Such cuts would have to be made either by hand or by using specialized types of machinery that would have to be developed. Both methods would prove costly.
Another method of road-to-vehicle communication substitutes the car for the record player and the pavement for the record. In theory this idea is simple and is illustrated in Figure 6. Just cut longitudinal grooves in a pavement which will correspond to cuts in a record. These cuts will be spaced to a scale set by the speed of passing automobiles. Next, cut enough longitudinal grooves in the pavement to assure that most vehicles will pass directly over a groove. Then install an enlarged "phonograph" needle, amplifier and speaker in the vehicle. Place a magnet on the needle. Place magnets of unlike poles and like polarity in the pavement at the beginning and end of each of the record grooves respectively. As the car passes, the "receiving" magnet attracts the car magnet and pulls the needle down to the groove. The needle then will pick up the physical vibrations as it moves along the groove which will then be converted to an audible message. When the vehicle reaches the other end of the grooves, the pavement magnet will automatically repel the needle. The needle will be conveniently stored underneath the car frame.

In conjunction with this research paper crude tests were made of this system. Using a scaled down model car, a crude phonograph needle, and a crude record from a child's toy, a somewhat parallel situation to that previously described was tried. The results convinced the author that the system would probably work.
Although the "Record Player and Record" system shows more of a possibility of working in the near future than does the transverse saw cuts method; it has most of the same drawbacks. The longitudinal cuts would wear out relatively fast, each automobile would have to be equipped with a sound pickup system which would increase the price of a car, and such cuts whether done by hand or by a special machine would be expensive.

The "Xylophone" Method

The "Xylophone" Method will work, at least as far as musical tones are concerned. However, this method will be extremely impractical, and if it is ever used it will probably be used just as a novelty.

The theory behind the system is extremely simple. "Keys" of various tonal pitches are placed in the roadway in such a way as to respond as the car tires hit them or as the car moves over them. If this system were to be used a musical code will have to be worked out. One musical tone sequence would mean stop, another would mean school zone, another would indicate a sharp curve ahead, etc.

A crude system was tested by the author where a children's xylophone was placed underneath a section of a Hot Wheels model racing car roadway. The results of that experiment proved that such a system could work. However, such a system would be expensive to install and would be of limited usefulness.
Miscellaneous Systems

Another system that might work would involve the automobile as a tape player and would use a magnetic type of tape along the pavement. Another idea would be to use a bell code system that would use a series of bells such as those in most service stations. As the vehicle runs over the "bell cables," the various bells would sound out a code that would specify an upcoming stop sign, railroad crossing, etc.

Still other systems also have possibilities, but the most feasible system to date seems to be the roadside-to-vehicle system proposed in Chapter I of this report.
REFERENCES


APPENDIX
STATE OF FLORIDA

DEPARTMENT of TRANSPORTATION

April 11, 1972

Mr. Gary J. Xanthos
U-716 Deseret Towers
Provo, Utah 84601

Dear Mr. Xanthos:

Secretary Mueller has forwarded me your letter of March 30, 1972, in which you inquire about the effects of tire noises associated with transverse saw cuts.

The Florida Department of Transportation’s experience with transverse saw cuts is extremely limited. Several years ago, we experimented with transverse saw cuts for the specific purpose of producing a noise to warn motorists of changing traffic conditions at a limited number of locations. Our principal experiment was on U.S. 1 in St. Augustine, Florida, on a concrete pavement where we cut grooves 1/8" wide, 1/8" deep, at 1" centers, transverse to the pavement locations where the speed limit changed from 65 miles an hour to 45 miles an hour. We also placed cuts at closer spacings at approaches to some traffic signals. The purpose in these saw cuts was to produce a noise or rumble effect to warn the driver of changing conditions.

We also made installations for a similar purpose in the Miami area on concrete pavements and did some grooving of asphaltic pavements in the Gainesville, Florida area.

I am sorry to report that the results of this experimentation were entirely negative. The level of noise produced by the patterns that we cut into the pavement were not high enough to alert the driver. In fact, they were barely discernible over other road noises with the window open. With the window closed, as is the usual case with the driver using air conditioning in Florida, you could not detect the cuts at all.

Very truly yours,

William Gartner, Jr.
Deputy State Highway Engineer