Testing for FM Radio Interference in Motor Vehicles

Donald J. Lewis

The increased use of electronics in modern vehicles has led to compatibility problems between vehicle electronic systems and after-market electronic equipment typically installed in Texas Department of Transportation (TxDOT) vehicles. Radio frequency interference (RFI) between these electronic systems frequently produces random failure of both original equipment manufacturer and after-market components. Interference with TxDOT onboard two-way communication systems can significantly reduce the useful communication range. This interference problem must be analyzed and studied from the standpoint of the FM two-way radio's characteristics and the automotive systems. Other system interference problems can also occur. Failures of critical vehicle systems due to RFI can adversely affect the operation of these vehicles and pose grave safety problems. Guidelines for minimum acceptable RFI limits in motor vehicles must be examined and improved. The overall objective of this project is to develop and validate effective RFI test procedures that will allow TxDOT to identify potential compatibility and RFI problems related to the use of after-market equipment in its vehicles. The first step in this process will be to investigate RFI problems and current RFI test standards. After this review process, a detailed test procedure will be developed. The second phase of the project will be validation of the test procedure. The RFI test procedure to be developed will benefit not only TxDOT but other DOTs across the country as well.

The substantial and continual increase of microprocessor-based electronics in modern vehicles has led to compatibility problems between vehicle electronic systems and after-market electronic equipment typically installed in Texas Department of Transportation (TxDOT) vehicles. Radio frequency interference (RFI) between these electronic systems frequently produces random failure of both original equipment manufacturer (OEM) and after-market components. Interference with TxDOT onboard two-way communication systems can significantly reduce the useful communication range. Failures of critical vehicle systems such as engine control, antilock brakes, and air bags due to RFI can pose grave safety problems and adversely affect the operation of these vehicles.

RFI sources of particular concern include high-power, two-way mobile radios (multiple frequencies) and after-market alternative fuel conversion kits using microprocessor controllers. Although extensive RFI testing by vehicle manufacturers typically provides adequate protection for OEM-installed electronics, there is evidence of after-market equipment compatibility problems with two-way mobile radios, cellular phones, after-market alternative fuel conversion systems, and personal computers that merit both radiated and susceptibility RFI tests to include such equipment. Proper filtering of OEM systems appears to be insufficient with regard to compatibility with these common add-on systems.

There is a requirement to establish guidelines for minimum acceptable RFI limits in motor vehicles. Thus, the problem at hand is to develop and verify a test procedure that will identify potential RFI problems with both OEM systems and after-market systems and that is acceptable to both TxDOT and vehicle manufacturers.

It should be noted that TxDOT depends heavily on the reliable use of two-way radios (47 MHz) to conduct daily business. Reliable radio communication is critical

Texas Department of Transportation, General Services Division, 125 East 11th Street, Austin, TX 78701.

to TxDOT's successful operation. The RFI test procedure to be developed will benefit not only TxDOT but other DOTs across the country as well.

SIGNIFICANCE OF WORK

Radio frequency interference between electronic systems, although not a new problem, has become increasingly important. Modern aircraft are examples of systems with many complex electronic subsystems that must continue to work correctly in electrically noisy environments. A system with known components and a known layout can be tested for interference problems, and the problems can be corrected. However, if an additional electronic subsystem is added to the system later, there is no guarantee that the new system will not produce or receive interference.

This problem is particularly pronounced in new automobile systems. Modern cars can have multiple microprocessor-based systems that communicate with a variety of sensors and actuators throughout the vehicle. These are primarily digital systems operating at relatively high frequencies. The switching of the digital circuits generates even higher frequencies over a broad range of frequencies. Electromechanical systems, such as solenoids and electric motors, also generate electrical noise. Of course, the best-known noise source in an internal combustion engine is the ignition system.

Vehicle manufacturers go to great efforts to ensure that all the subsystems in a vehicle work correctly and are not affected by any electrical noise generated within the vehicle. To some extent, manufacturers also ensure that the vehicle works correctly in the presence of external interference signals. However, the manufacturer cannot test the vehicle under all conditions for after-market subsystems added to the vehicle. After-market items such as two-way mobile radios, cellular phones, alternative fuel conversion systems, and personal computers may cause problems with the existing vehicle electronic subsystems. In addition, the vehicle's subsystems may interfere with these added-on systems.

The SAE has been involved in writing electromagnetic compatibility standards since 1957. These standards are continually examined and updated to keep pace with technology. Comparable European standards also exist. Other organizations have developed standards for electromagnetic compatibility with many other systems. The U.S. military, the IEEE, and the American National Standards Institute (ANSI) all have a number of standards concerning electromagnetic compatibility.

The problem with developing a standard that takes after-market items into account has to do with the ways that electrical signals can be coupled between systems. For example, a two-way radio can produce or receive interference. The coupling can be through the antenna, the antenna cable, the power supply cables, other cables connected to the radio, or the radio's enclosure by direct radiation. Thus, the interference may be related not only to the radio and the vehicle but also to the way the radio is installed.

One approach to determining possible interference problems is to test the vehicle after the after-market items have been installed. Finding and fixing these problems, however, are time-consuming and expensive. In addition, they must be repeated every time there is a change or an addition to the vehicle's electronics. This is why standards are developed—to indicate to all parties (vehicle manufacturers, after-market vendors, and customers) what is required for their systems to work together without problems. The standards for electromagnetic compatibility must indicate not only acceptable limits but also how to measure the limits. This is crucial because of the wide variety of configurations that can exist.

It is also important that the add-on equipment, such as the FM two-way radio, be analyzed and studied to determine the processes by which it filters and/or preprocesses radio signals. This is essential in determining the cause and cure of interference problems.

Although the development of standards and standard test procedures sounds straightforward, it is very difficult because of the many ways interfering signals can be coupled. Standards must take all these possibilities into consideration. Historically, most of the disturbances in radio receivers in vehicles have been coupled through the antenna. However, this applies primarily to standard receivers in a fixed location in the vehicle and not as much to add-on two-way radios.

Radio frequency interference between these electronic subsystems can be a major problem. Interference with onboard two-way communication systems can significantly reduce the useful communication range. Interference may cause failure of critical vehicle systems that could adversely affect the operation of these vehicles and pose grave safety problems. New standards that address these issues are definitely needed.

BACKGROUND

The recent avid use of microprocessor-based electronics in modern automotive applications has led to problems of compatibility between various pieces of after-market electronic equipment installed into the vehicular environment. As such, RFI between electronic systems has grown to such a magnitude that random failure of key automotive systems, both OEM and after-market, can affect the safety and operation of these vehicles.

Growing concerns of RFI failures involving anti-lock brake system and engine real-time management systems have become valid. Possible interference with air-bag deployment control systems is a concern. RFI sources that should be investigated include high-power, two-way mobile radios (multiple frequencies tested) and after-market alternative fuel conversion kits using microprocessor controllers.

Although extensive RFI testing by the OEM community apparently provides sufficient protection for OEM-installed electronics, there is evidence of after-market equipment compatibility problems (including two-way mobile radios, cellular phones, after-market alternative fuel conversion systems, and personal computers) that merit both radiated and susceptibility RFI tests to include such equipment. Proper filtering of OEM systems appears to be insufficient with regard to compatibility with add-on systems discussed above.

TxDOT continues to have problems associated with RFI in many aspects of its vehicular fleet. Although a test method was developed for detecting out-of-bound limits of high RFI levels in vehicles, RFI-related problems are not diminishing. Each new model year brings a new rash of problems, some the same, most unique. It is believed that the solutions (ultimately) will rely on the major vehicle manufacturers' adopting standards developed or initiated by TxDOT in order to be successful.

TxDOT has associated itself recently with SAE and its subcommittee on electromagnetic compatibility (EMC) charged with researching these issues. SAE currently does not have a test method for detecting the types of RFI considered important to the department. The closest test, SAE Test Method J551/4, -12, is inadequate for TxDOT needs and was recognized as such by SAE. SAE has reviewed the TxDOT test and believes it too is inadequate. Further development is necessary, according to SAE.

In addition, TxDOT recently received a call from the AASHTO subcommittee on communications requesting a copy of the TxDOT test. Efforts seem to be under way within AASHTO to consider the TxDOT test a recommended practice. This development reinforces the indications that there is widespread interest in a viable RFI test and that this research project should be pursued at this time.

Objectives of Research

The objectives of the proposed study are to

- Investigate the problems related to RFI between vehicle systems and TxDOT two-way radio systems,
- Analyze and study the processes by which the FM two-way radios filter and/or preprocess radio signals,
- Develop a detailed test procedure acceptable to both TxDOT and vehicle manufacturers that will identify potential RFI problems,
- Develop guidelines for after-market electronic equipment specifications and installation to minimize potential RFI problems,
- Verify the proposed test procedure via testing, and
- Formulate a numerical model for predicting RFI problems.

Implementation

The test procedure and equipment guidelines that result from this project can be implemented by TxDOT to minimize or eliminate RFI problems between OEM vehicle electronics and after-market electronic components such as two-way radios, cellular phones, alternative fuel engine control systems, and others. The results will be forwarded to vehicle manufacturers and to the SAE's Electromagnetic Radiation/Electromagnetic Interference Standards Committee for consideration in future vehicle design. The project results will also provide specific RFI levels for after-market equipment. The results will be provided to all state DOTs and other government-based vehicle fleets.

What TxDOT Has Done

It is believed that the current TxDOT signal plus noise and distortion (SINAD) test has established a good starting point. Further development and refinement are needed. Results from this project are being coordinated with proper officials within the SAE's EMC subcommittee for possible inclusion in future SAE standards or development of new standards. Only then will recurring RFI problems be eliminated by the incorporation of their solutions into the vehicle during development by the major vehicle manufacturers.

Research Initiated by TxDOT

The overall objective of this research project is to develop and validate effective RFI test procedures that will allow TxDOT to identify potential compatibility and RFI problems related to the use of after-market equipment in department vehicles. TxDOT recently contracted with Texas Tech University, which in turn had entered into subcontracts with both Allied-Signal, Inc., and Southwest Research Institute, for project implementation.

Principally, TxDOT plans to correlate test limits established with a department-developed 12-decibel SINAD test with those of SAE J551/4, -12 Test Standards. The department operates many two-way, 100-watt FM mobile radios in the 47-MHz range (and higher). A growing number of

RFI-related or -induced malfunctions are experienced every model year. For example, mobile radio receiver sensitivity has been greatly reduced in many high-noise-environment vehicles, while 100-watt mobile radio transmission often causes random and erratic effects on the vehicle electronic subsystems.

Ongoing Tasks

• Standards search. A detailed search was performed of various Federal Communications Commission, SAE, and other regulatory standards and specifications that relate to automotive RFI issues.

• Test plan development. A test plan was developed that will define what equipment to test, what frequency range to test, whether radiated and susceptibility emissions should both be tested, and what level of compatibility is acceptable. Recommended wording for inclusion in procurement specifications for vehicles and ancillary equipment will be developed along with instructions for proper installation of after-market equipment.

• Testing. Sample vehicles from the three major OEMs will be tested for RFI compatibility using representative samples of after-market add-on equipment. Limits established by the OEMs should be used as test standards initially. New limits should be established as tests determine weaknesses and vulnerabilities. Suggested RFI test formats to follow include military standards for RFI testing (Mil-Stds 461/462).

• Reporting. Reports will be generated that will give all project specifics including literature search criteria, type of tests needed, and development of an RFI test plan.

Potential Implementation

This evaluation will be continued through FY 2000 due to the growing awareness of safety as a real concern and issue. Results from tests should be forwarded to the major OEMs for consideration of incorporation into future vehicular designs and to state DOTs for incorporation into procurement specifications. Guidelines for "after-market" equipment suppliers should be generated defining specific levels of RFI limit compatibility requirements (both radiated and susceptibility) to be met.

Incorporation of the results of these tests by the major OEMs would result in widespread effectiveness available not only to the relatively limited user community listed above but also to the general traveling public.