SUBSURFACE SENSING LAB
UNIVERSITY OF HOUSTON

Subsurface Sensing Lab
University of Houston

PROJECT SUMMARY REPORT

Project Summary Report 0-4509-S
Project 0-4509 Evaluate Innovative Sensors and Techniques for Measuring Traffic Loads

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Evaluate Innovative Sensors and Techniques for Measuring Traffic Loads

Transportation infrastructure is the lifeline of the nation. An efficient and safe road network allows goods to reach the markets quickly, thus, stimulating economic activity and ensuring trade competitiveness. According to the Highway Statistics, in the United States, over 46,000 miles of interstate roads, combined with a network of almost 4 million miles of other roads, makes up the nation’s lifeline. Each year, nearly five trillion dollars’ worth of goods is transported via the nation’s lifeline via commercial trucks. Unfortunately, commercial truck traffic also contributes greatly to the cost of deteriorating highways across the nation. The increased costs of maintenance, combined with the diminished highway funds available, have meant that many roads are now in or rapidly approaching a critical condition. Industry experts estimate that there is currently a $300+ billion shortfall to repair roads and bridges to an acceptable standard. For many years, states have been looking at developing a system that can be beneficial to the trucking industry, taxpayers, and the states, while helping to protect the infrastructure. It is the Weigh-In-Motion (WIM) technology which provides benefits to all parties involved.

In this project, several piezoelectric sensors, fiber optical sensors, and an innovative microwave sensor were evaluated. The field-test site is located in a weigh station operated by Department of Public Safety (DPS) at a north-bound area of interstate highway I-45 about 60 miles north of Houston, Texas. The layout of the weigh station is shown in Figure 1.

What We Did …

To evaluate the WIM sensors and techniques, the WIM system standard is introduced. Available WIM sensors in the market such as load cell, bending plate, and piezoelectric sensor, etc, are reviewed. Then, a remote WIM system, shown in Figure 2, is designed and installed to

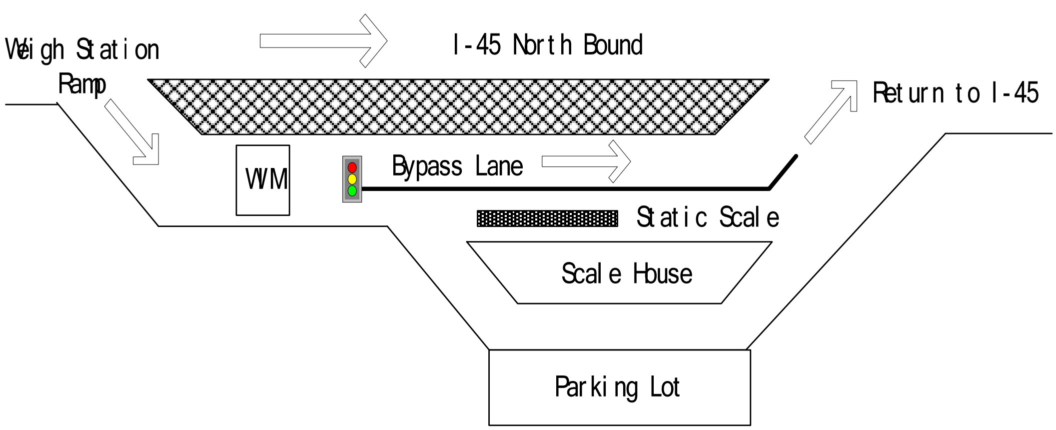

Figure1. Weigh station layout

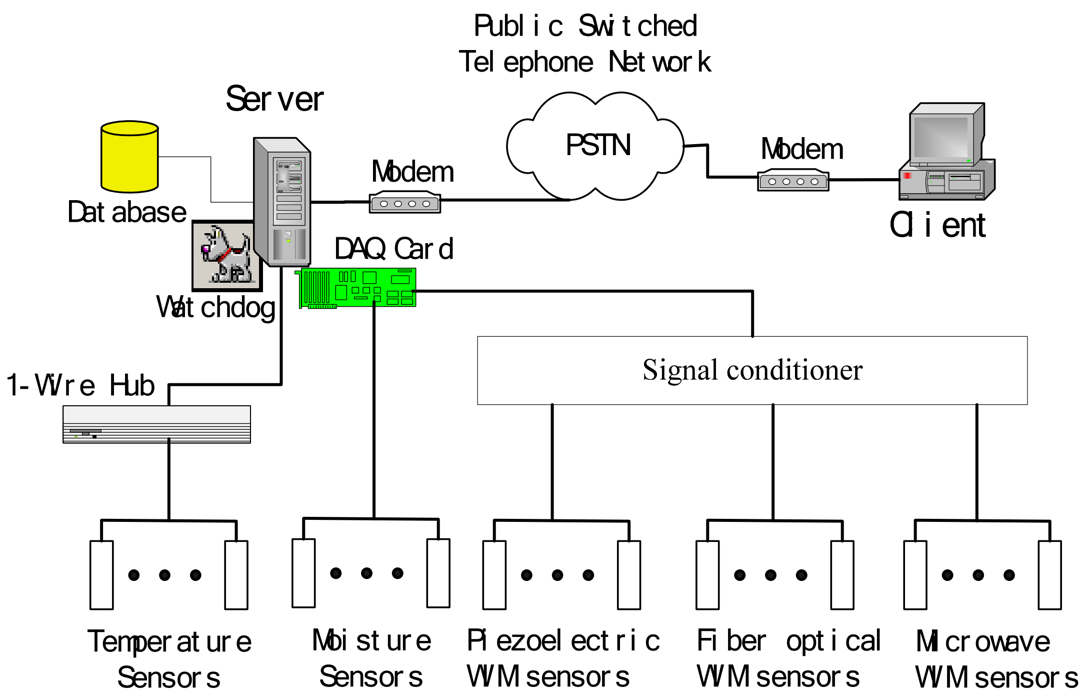

Figure 2. Structure of remote WIM system

conduct the evaluation of the sensors. The designed system can be accessed remotely and is capable of conducting data acquisition for multiple sensors. To realize the remote functions, a broadband internet connection or phone line is necessary.

Since the system operates in the harsh environment near highway, a Linux operation system is selected for its reliablity. The Linux computer provides telnet, ftp, and http services, etc.

To manage vehicle and environment data, including axle weights, vehicle speed, axle distance, temperatures, moistures, etc., Mysql database is installed and configured in the Linux computer.

In order to evaluate piezoelectric sensors, products from three major vendors (Measurement Specialties Inc, Thermocoax, and ECM) are installed in the WIM zone.

Two FBG sensors were also evaluated in this research. One was developed by the researchers, and the other one was developed by Intelligent Fiber Optic System (IFOS).

In addition to the evaluation of commerical WIM sensors, an innovative microwave WIM sensor, shown in Figure 3, was developed in this project. It is an active sensor based on the perturbation theory of microwave resonant cavity. The microwave signal generated by a circuit is coupled into the sensor, and the returned signal is measured to determine the weight applied to the sensor.

The sensors' installation is shown in Figure 4.

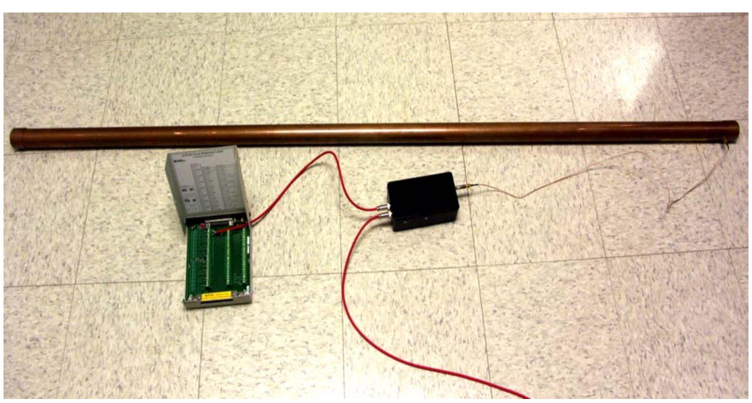

Figure 3. Innovative microwave WIM sensor

What We Found...

According to the field test results, the sensor from ECM shows the best performance with accuracy about 12-14% under

Figure 4. Sensor installation in New Waverly, TX.

95% confidence requirements by integration algorithm.

With the acquired field data, a pavement deflection weight determination algorithm is developed, and the results are compared with the integration algorithm. The analysis shows that pavement deflection can be used for vehicle's weight measurement. Both integration weight determination algorithm and the innovative deflection weight determination algorithm have good accuracy, but the deflection algorithm can be used to develop a new WIM sensor.

The FBG sensor is a very good candidate for the WIM system. Compared to piezoelectric sensors, FBG sensors offer a simpler and more explicit weight determination algorithm, and the life span of the sensors is longer. However, it is necessary to build a sensor holder for an FBG sensor. For the current FBG WIM system, the vehicle has to contact the same position of the sensor area to obtain accurate results. This is a limitation in the current FBG sensor holder. Meanwhile, the bandwidth of the current laser source used by the developed detector is not wide enough, which limits the measurement range.

With the designed circuit and sensor head, a lab test is conducted for the microwave WIM sensor by using a load machine. The linearity, uniformity and measurement accuracy are tested. The sensor is found having a satisfactory linearity and uniformity, and with a heavy load applied on the sensor, measurement error is within 10%.

A comparison of the sensors is shown in Table 1.

The Researchers Recommend…

- The piezoelectric sensor from ECM is recommended for low to medium application.
- Both integration weight determination algorithm and an innovative deflection weight determination algorithm have good accuracy, but the deflection algorithm can be used to develop a new WIM sensor.
- The FBG sensor has some merit, but the current FBG sensor holder should be improved to get better measurement results. Meanwhile, the bandwidth of the current laser source is not wide enough, which limits the measurement range.
- The innovative microwave WIM sensor was tested in the lab. It is a high-accuracy, low-cost sensor. More field tests are needed to confirm that the sensor meets all design goals.

Table 1. Comparison table of different WIM sensors

	Piezoelectric	Bending Plate	Load Cell	FBG	Microwave Sensor
Accuracy	Low	Medium	High	Depending on the sensor holder	High
Expected Life	Short	Medium	Long	Long	Long
Sensor Holder	No	No	No	Yes	No
Installation	Easy & Low cost	Hard & High cost	Hard & Very High cost	Depending on the sensor holder & Medium cost	Easy & Low cost

For More Details...

This research is documented in: Report 0-4509-1, Evaluating Innovative Sensors and Techniques for Measuring Traffic Loads: Final Report

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