EMC AND RELATED PROBLEMS IN THE IMPLEMENTATION OF URBAN TRAFFIC MANAGEMENT AND PUBLIC TRANSPORT MANAGEMENT SYSTEMS

Marius MINEA, Angel Ciprian CORMOŞ

"Politehnica" University of Bucharest, Transports Faculty, Telematics and Electronics for Transports Dept.
mariusminea@yahoo.com, angel_cormos@webmail.pub.ro

Abstract **– This paper presents several electric, electromagnetic compatibility and communication, specific problems, encountered in the process for the implementation of an Intelligent Transport System for Bucharest, composed of an Urban Traffic Management subsystem (UTC) and a Public Transport Management (PTM) subsystem, along with a Closed Circuit Television (CCTV) subsystem. Mainly the problems of the compatibility between low energy signals used by traffic sensors or onboard equipment and power traction or vehicle supply are discussed in this paper.**

Keywords: *Intelligent Transport Systems (ITS), electromagnetic compatibility, passive infrared (PIR) sensors, onboard equipment units (OBUs) power surges and suppressors .*

1. INTRODUCTION

Background information: in Bucharest, the Municipality has applied for an EBRD funded loan, to build an integrated UTC/PTM/CCTV complex system. Such an implementation is an European premiere, as no country has done this before. There are separated subsystems in developed countries as: UK, Italy, Belgium, Austria, Germany, France etc., but starting with a complex integrated system from the beginning represented a real challenge. On another hand, our TET department in the faculty has its own research centre, and several, similar projects are developed in this environment. Some of these projects are related with traffic management and environmental surveillance in Suceava, including installation of a newly developed system with infrared sensors for vehicles, CCTV camera with IP (for direct Internet access) and environmental sensors. There are many different detection systems available. Each has strengths and weaknesses and are appropriate for a variety of circumstances. The installation process for these sensors and ancillary equipment involves special measures to be taken, in order to avoid interference with disturbing signals. These signals can be issued either by the public transport power supply (trolleybuses and trams) or by local power supply, onboard vehicles. Several measurements carried on and technologies used for protection are presented.

2. VEHICLE SENSING IN UTC/PTM/CCTV COMPLEX ADAPTIVE SYSTEMS AND SPECIFIC PROBLEMS

The essence of an adaptive UTC/PTM/CCTV system is to be able to respond to the peaks and troughs of traffic demand, accommodating the normal temporal variance in flow in normal and non normal conditions. To be able to do this, the system needs to "know" where the demand is in the network so that it can respond to it in an optimum manner. An array of detection zones is necessary to be able to calculate the critical areas of congestion and consequently calculate the most efficient timings to be able to alleviate the problem.

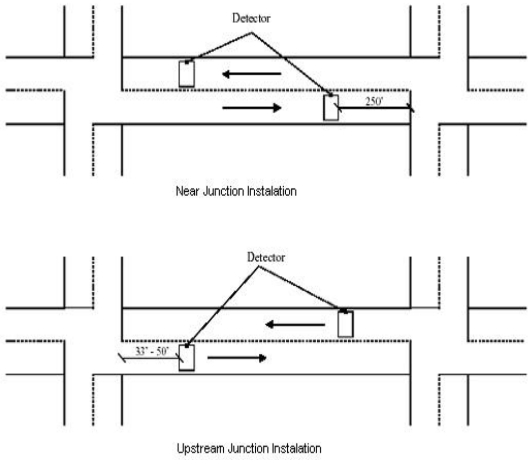

Figure 1: Principle of the traffic detection using inductive loops

The detector types used for vehicle presence, speed, classification and/or other functions can be divided in two main categories:

- *Intrusive detectors,* that usually need operations for installation, with temporary closing of the road traffic; in this category:
  - *Inductive loops;*
  - *Magnetic sensors;*
  - *Capacitive sensors;*
  - *Piezoelectric sensors;*
  - *Pneumatic sensors;*
  - *Pressure detection tapes etc.*

- *Non-intrusive detectors,* that do not need traffic interruption for their mounting aside the road; in this category:
    - *Passive or active infrared sensors;*
    - *Microwave sensors;*
    - *Passive acoustic areas;*
    - *Video processing systems etc.*

Despite the usage of a buffer stage, or amplifier, for the sensors placed in the vicinity of the road, in some cases special measures are to be undertaken for the correct operation of these devices. Some of these cases are:

- When the distance between the sensors and the traffic controller exceeds 50 m;
- When the sensors feeder cables extend in parallel with power supply cables, or in the same ducts, for longer than 50 m distances;
- When some categories of sensors are placed in the vicinity of the supply lines for trolleybuses, trams or in the vicinity of line automatic switchers;
- When sensors are placed onboard vehicles;
- Other, specific cases.

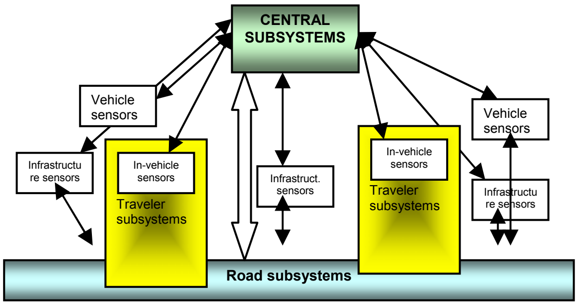

Figure 2: Main placements of sensors in UTC/PTM/CCTV integrated systems

Figure 3. Example of a mounting of an inductive loop in the road

When video systems are used, then the camera or cameras are usually located above and looking down at the junction scanning each approach using virtual loops and operate much in the same way as an embedded loop system, it is only the method of detection that is different, not the way the adaptive software algorithms use the data. Usually, for this mounting, if the camera is in the vicinity of an automatic line switch for trolleybuses, interference may occur in the signal transmission.

For systems that have upstream detectors, the length of any accumulated queue can be detected, monitored and ultimately dealt with. This is, of course, with the caveat that the upstream detector is beyond the amassed queue.

These systems imply long distance detectors. Special protection measures are to be taken for the transmission of the data signals, especially in the above mentioned cases. Usually, the employment of a RS485 serial transmission is recommended, as the noise gap is larger.

Detection may also be used for pedestrian movements at traffic signals and for local vehicle actuation purposes. The use of a fully traffic adaptive system generally eliminates the need for local vehicle actuation except as a possible backup facility or for introducing minor stages only when there is actually a traffic demand for that stage. Whilst some traffic adaptive systems operate using stopline detectors similar to local actuation detectors, for systems with upstream detection the local stopline detectors become an unnecessary duplication of resources and are usually made redundant and not maintained.

Other applications for vehicle detection include:

- Vehicle classification;
- Parking guidance, car park in/out counting;
- Access control;
- Speed warning and enforcement;
- Over-height and overweight detection.

Vehicle classification can be performed using either loop detection or overhead detection methods developed specifically for this specialist application. Vehicle classification information is not usually regarded as real-time data, but may be collected and stored locally and then uploaded to the control centre on a daily or weekly basis. In any case, a data transmission in an EM disturbing environment is necessary.

Access control systems are now being used in urban areas to restrict access to private cars to pedestrian precincts or other sensitive areas. Access control equipment includes mechanical lifting barriers or rising bollards that are used to block normal vehicular access except for certain recognized vehicles. Permitted vehicles such as buses and emergency service vehicles may be allowed access automatically by means of Special Vehicle Detectors (SVD), Tag-Transponder systems or Automatic Number Plate Recognition (ANPR). In some cases access is only permitted by manual intervention of control centre staff. In addition to these automatic entry detection methods for access control, loop detectors are commonly used to ensure the barrier is not returned to the 'closed' position until the vehicle has cleared safely.

Vehicle detectors are also used to trigger speed warning signs and also to trigger speed enforcement cameras and red light running cameras.

Specialist vehicle detectors are used to detect the height and weight of vehicles, to warn drivers in advance of height and weight restrictions ahead of them. Over-height detectors may be optical beam transmitter-receiver units. Overweight detectors are based on ruggedised loadcells. Both of these means of detection may be triggered by vehicles exceeding a preset height or weight threshold and used to display a warning sign to the driver of the vehicle before damage is done to either the vehicle, bridge, or weak road structure.

3. PROTECTION OF DATA TRANSMISSION IN TRAFFIC SENSING

In some special situations, as mentioned above, specific protection measures, including supplementary electronic devices introduction, groundings etc. are needed in traffic sensing process.

3.1. Protection for road-side detection equipment

The inductive loops usually include a specific coil, of around 0,8 – 1 m diameter, rectangular shaped, mounted below the road pavement, at a depth comprised between 0.05 – 0. 1 m. The vehicle is sensed thru the modification of the inductance of the loop, caused by the metallic mass of the vehicle chassis.

PIR sensors are usually mounted above the road lanes, on poles or cantilevers. Sometimes, trolleybus power supply lines are on the same poles and surges can influence the normal operation of these sensors, if they are not protected against EM disturbances.

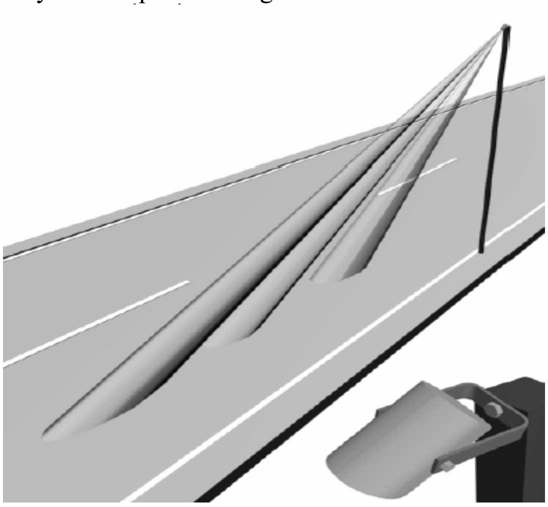

Figure 4. Mounting of a PIR sensor and beams for vehicle sensing

Some experiments have been carried on in order to determine if the signal in absence of a vehicle can be influenced by the presence of a power supply line of a trolleybus. The figure below presents the signals recorded in several cases. For this experiment, a specific firmware application was used.

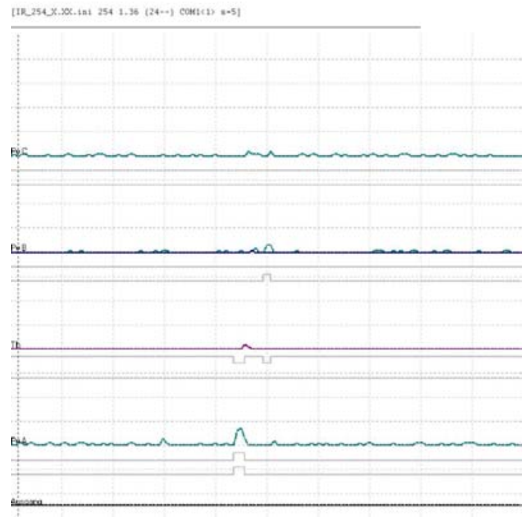

Figure 5. Image of the recorded signals in absence of vehicles; the pulses represent noise

In order to reduce noise and influence of the EM environment in long data transmission cables, a RS 485 standard was adopted for these sensors communications.

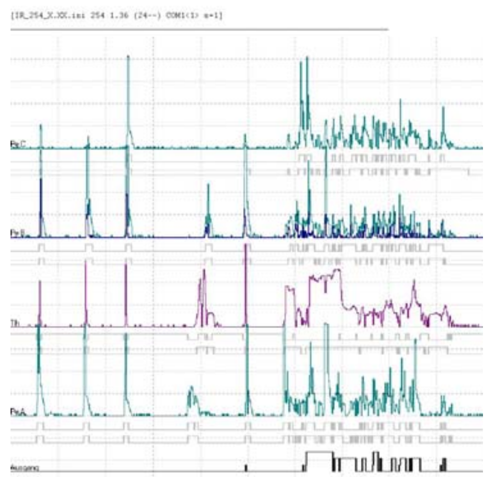

Figure 6. Image of the recorded signals with vehicles in range, during thermal stabilization phase of the sensors

The problem in this case is that thermal noise can influence the correct sensing of a presence of a vehicle in the active area. It is recommendable that the system uses specific delaying of the initial startup in detecting vehicles.

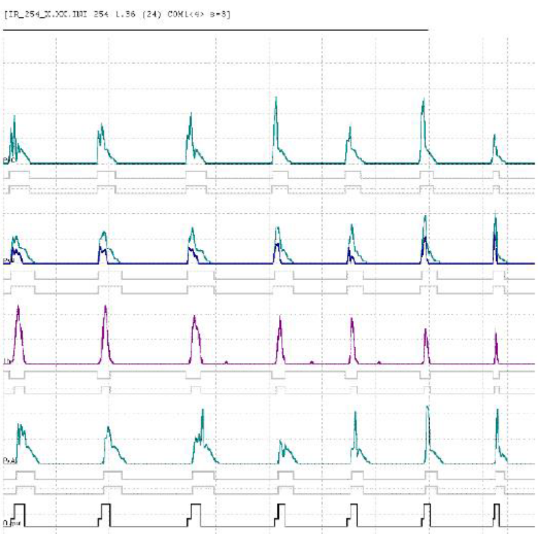

Figure 7. Correct detection signals, after applying protections and in normal operation phase of the PIR

The conclusion was that using the recommendations of the producer, and completing with specific measures to reduce specific electromagnetic interference, the detection process in presence of the power lines of a trolleybus can be performed satisfactorily.

3.2. Protection of in-vehicle equipment

The main problem for the in-vehicle equipment is the engine of the vehicle. There are separate cases for public transport vehicles: buses use fuel engines, with ignition system, and trolleybuses and trams use electric engines (usually d.c., 750 V).
Some measurements on the voltage supply onboard the vehicle have been performed, in order to determine either the spikes created by the engine of the bus are able to disturb the normal operation of the equipment. Some of the mobile equipment, in UTC/PTM/CCTV systems, use data transmission of some parameters to a central management point, It is mandatory that the capture of the parameters onboard the vehicle is operating without problems that can be caused when the engine is functioning, no matter if it is a fuel or an electric engine.
Among the main noise sources onboard a vehicle there are:

- Ignition equipment of the vehicle;
- Lighting onboard, if it is fluorescent;
- Electrical engines for different parts;
- Power electronics (power supplies, choppers, rectifying systems, refrigerating equipment, relay driven equipment etc.);

There are also noise receivers that can be disturbed by these emissions in the normal operation regime:

- Automated, low signal systems;
- Microelectronics onboard the vehicle;
- Measurement, command and control equipment;
- Data processing equipment;
- Remote controlled installations etc.

If the vehicle uses also a GPS receiver, for positioning purposes, it is very important to place the antenna for this device in an open location, far from noise generators.
The communication equipment can be affected on the following paths:

- Supply ducts, strongly affected by noise, due to the long distance between the vehicle's battery and the backup equipment battery;
- External electromagnetic disturbing generators;
- Internal electromagnetic and radio interfering equipment (even the GSM modems) etc.

The board computer and ancillary equipment, used for remote data collection from vehicles in UTC/PTM/CCTV systems can be disturbed from correct operation on the following parts:

- Source noise: placing transducers in appropriate locations and connecting ground efficiently can reduce a significant part of the noise; it is also recommendable that the connection wires between the low signal transducers and their correspondent signal amplifiers to be as short as possible;
- Wiring and ducting: it is recommendable that the paths chosen for the low signal cables to be chosen very carefully, in order to avoid as much as possible parallelism with power supply cables;
- Galvanic separation and filtering of the supply lines for the low signal equipment represent also some specific requirements;
- Mounting the onboard computers in shielded and IP65 protected boxes etc.

Usually, for the onboard equipment in UTC/PTM/CCTV systems there can be two kinds of interferences:

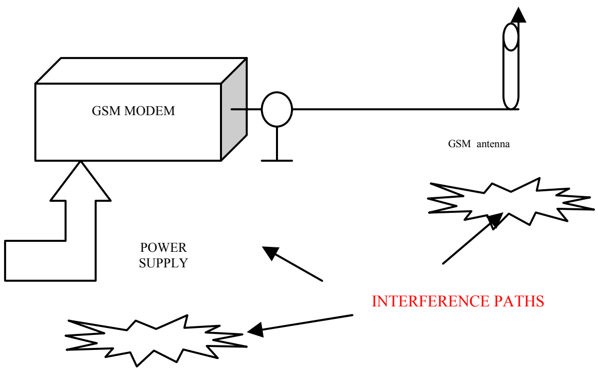

Figure 8. Interference paths onboard a vehicle equipped with remote capture of data

- Interferences that produce temporary functionality reduction – admissible;
- Interferences that produce erroneous functioning of the equipment – not admitted.

For appreciating the amount of noise, usually there are used logarithms of the quantities ratios measured. In all cases, it is important that significant noise gaps are left in the normal operating signal states, if logic signals are used for.

$$E_{dB} = 20g\frac{E_x}{E_0} dB_{\mu V/m} \qquad (1)$$

represents the level of the electrical field level, with the reference value of

$$E_0 = 1\mu V/m \qquad (2)$$

and

$$H_{dB} = 20\lg\frac{H_x}{H_0} dB_{\mu Am} \qquad (3)$$

Represents the level of the magnetical field level, with a reference value of

$$H_0 = 1\mu A/m \qquad (4).$$

These measures are frequently used in evaluation of the EM environment onboard a vehicle.

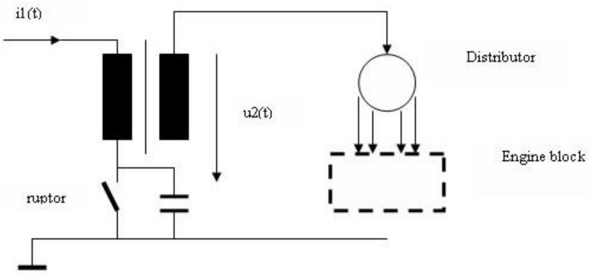

Figure 9. Main interference generator onboard ignition engines vehicles

The typical noise level produced by the electrical field in the nearby of a vehicle's engine is around –20 şi +20 $dB\mu V/m/kHz$ (amplitude densities), and considering the superior frequencies, these are placed up to the GHz range.

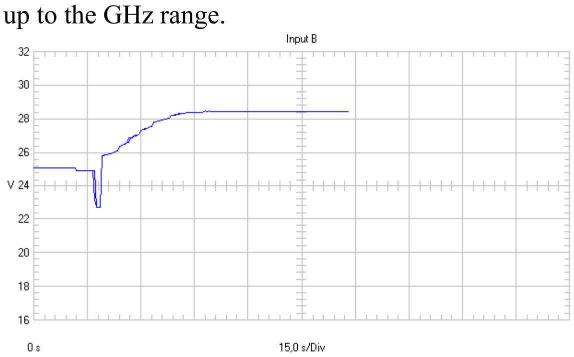

Figure 10. Measured voltage on the vehicle's battery when starting the engine

$$\Delta U = U_{max} - U_{min} = 28{,}3 - 22{,}4 = 5{,}9V \quad (5)$$

represents the maximum difference in amplitude between the peak and lowest values of the power d.c. supply. The measured signal-to-noise ratio was:

$$RSZ_{Ual} = 20\lg\frac{U_{nom}}{\Delta U}[dB_V]; \qquad (6)$$

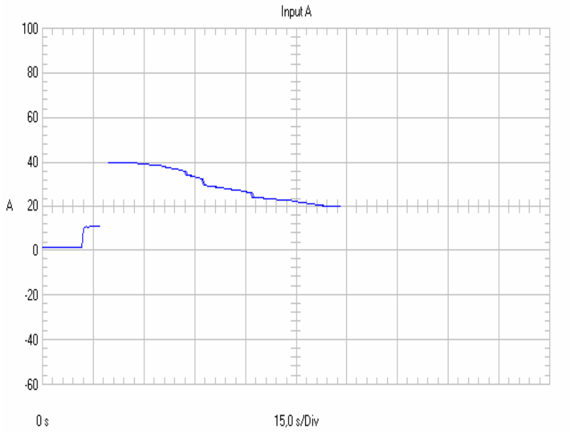

Figure 11. Measured peak current when starting the engine of the vehicle

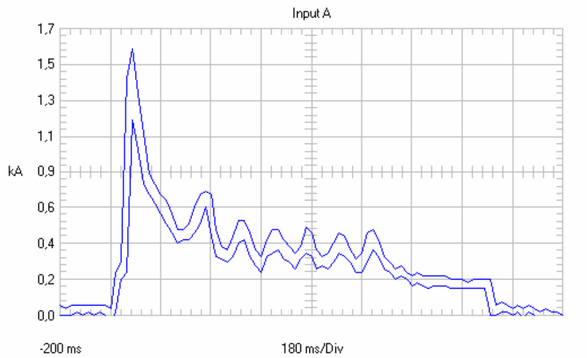

Figure 12. Disturbative regime when starting the engine

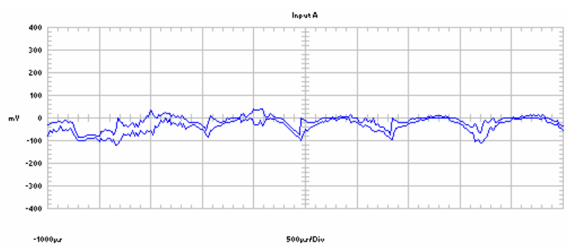

Figure 13. Noise levels on the D.C. power supply line onboard a vehicle, in normal conditions

4. CONCLUSIONS

Reliable capture of data from a set of vehicles implies several equipment and chain operations, such as communications to work reliable in an EM noisy environment. When low signal equipment is placed onboard a vehicle, special protective measures have to be undertaken. Good, reliable communications are vital for any advanced UTC/PTM/CCTV system. Without the communications, system performance is severely degraded. Within any UTC/PTM/CCTV system, communications to roadside infrastructure and vehicles, functioning of the onboard equipment in noisy environmental electromagnetic conditions are required to be approaching 100% reliable and virtually 100% available.

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