AUTOMATIC VEHICLE IDENTIFICATION
AND ITS APPLICATION TO INTER-URBAN ROAD PRICING

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In May 1992 the DART-Tag Automatic Vehicle Identification (AVI) system was launched at Dartford River Crossing for the non-stop cashless collection of tolls. This was the first full working system of electronic cashless toll collection in the UK and currently has in excess of 23,000 users. The French manufacturer CSEE Péage, along with their UK subsidiary RTI Systems Ltd, saw their second major UK AVI toll collection system (FAST-Tag) launched in December 1992 at the Mersey Tunnels. It currently has over 13,000 users.

This paper discusses the requirements for remote identification systems and explains why microwave based techniques are best suited to AVI. A detailed description of DART-Tag follows, covering its lane equipment, computer system and associated real-time distributed database technology. Finally, recent developments in the application of AVI to a European inter-urban road pricing scheme are summarised.

<u>Remote IDentification (ID)</u>. There are many techniques readily used for automatic identification, *e.g.* Optical Character Recognition (OCR), bar code reading and magnetic card systems. These methods only work over a relatively short distance. Technologies better suited to remote identification like AVI include: Infra-Red (IR), Radio Frequency (RF), camera/vision and inductive systems. Some of the factors to be considered for remote identification of an object are as follows:

- Range - Distance between the object being detected and the identifier;
- Data Rate - Determined by the range and speed of the object and the amount of related data being transferred;
- Read/Write Capability - Programmable ID systems allow the information in the ID tag to be changed and form the basis of a decentralised information system, *e.g.* smart-cards;
- Security - Important with programmable ID tags, as it is possible to encode the information for higher data integrity;
- Environmental Conditions - The ID system should be resistant to shock, vibration, aggressive fluids and vapours, extremes of temperature, electrical and magnetic interference, *etc*. It may also need to penetrate water, snow, ice, dirt, paint, glass, *etc*.
- Positioning Tolerance - Remote ID systems should feature high positioning tolerance in terms of distance, angle, tilt, rotation, *etc*.
- World Regulations - Any remote ID system should conform to World Health Organisation (WHO) and International Telecommunication Union (ITU) regulations.
- Reliability - The risk of misreading/writing ID tag data should be kept to a minimum and the MTBF for the system hardware to a maximum.

<u>System Components</u>. All remote ID systems consist of a communicator and an ID tag. There are three types of tags, namely: active, passive and semi-passive. Active tags rely on an internal battery to generate the energy needed to receive and transmit signals. They tend to have a limited battery life, due to the constantly high power requirements. Passive tags have no internal power source, but certain types can be energised by means of an electromagnetic field. Their major disadvantage is a limited operating range.

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Semi-passive ID tags merely reflect the incoming signal from a communicator, after modulating the tag's information onto it. The internal battery provides power for memory storage and signal modulation when required - a long battery life therefore results. All the aforementioned factors can be accommodated by a semi-passive microwave based system.

<u>Programmable REMote IDentification system (PREMID)</u>. PREMID was developed by Philips from an automotive factory system into the AVI system used throughout the world today. The PC3000 model, as used at Dartford and Mersey, features a semi-passive tag measuring 60mm x 70mm x 12mm.

The ID tag is placed inside the vehicle's windscreen - the exact location being determined by the position of the detecting antenna and its associated microwave lobe. A carrier frequency of 2.45GHz is used, inside the world-wide Industrial, Scientific and Medical (ISM) band. The antenna transmits information via Pulse Coded Modulation (PCM). Data from the ID tag is relayed via Frequency Shift Keying (FSK) Single Side Band (SSB) modulation, where "1" corresponds to a shift of 25kHz and "0" a shift of 28kHz.

The tag's memory can store 128 bits of data, which may be formatted to meet user requirements. Levels of reading accuracy better than 1 error in 400 million readings can be achieved with coded formats containing 20 decimal digits. By only utilising half of this storage capacity, vehicles can be correctly identified at over 100mph. The specified data rate of 3.1kByte/s means that a tag can be read in almost 40ms. With an expected battery life of at least 5 years and an MTBF of 200 years, the PREMID system is highly reliable.

<u>Transaction Sequence</u>. In order to determine the toll due, the vehicle type must be identified or *classified*. Both at Dartford and Mersey, classification is undertaken by an operator using a Manual Toll Terminal (MTT) keyboard. The CSEE lane equipment then instructs the PREMID communicator to start polling the antennae. Once the tag has entered the microwave lobe, its unique 10 digit ID number can be read. This contains the account number, user number and vehicle classification.

The MTT now checks its tag blacklist, in case the tag has been reported stolen, lost, misused or unpaid for. A flashing red AVI light is displayed on the lane to alert both the driver and the operator in this case. If the tag is not blacklisted, the MTT checks its whitelist - which holds the status of all 50,000 account numbers. A steady red AVI light indicates that the account is either exhausted or has yet to be opened.

In all other cases, the AVI light will turn green (indicating staus OK) or amber (for low credit). The traffic light now changes to green and the barrier is raised. When the vehicle enters the exit loop, payment is deemed to have been accepted by the system. The traffic light then turns red, the AVI light is extinguished and the operator can now classify the next vehicle. The barrier falls once the preceding vehicle has left the exit loop.

Some lanes are dedicated to cars only and are equipped with Automatic Coin Machines (ACMs) as well as an AVI facility. The classification is automatically processed when the vehicle passes over the entrance loop. It is theoretically possible for a lorry to pass through such a lane when using a car tag. Enforcement is carried out by means of Traffic Officers who patrol the toll plazas.

<u>Plaza Computer System (PCS)</u>. All lane equipment transactions and alarms are relayed to the PCS via the Real-Time Data Concentrator (RTDC). Directly connected to this is the Plaza Computer, which is running under a multitasking operating system. This manages the messages received by the RTDC, updating database files on the fileserver where necessary. It also sends black/whitelists and toll fare tables to the RTDC for subsequent downloading to the lane equipment. Compilation of black/whitelists is performed by a separate networked PC.

Customer accounts can be automatically credited via a Bank Automated Clearing System (BACS) file, containing details of direct-debits and credit card transactions. The Tag Administration and Test Computer (TATC) is used to manage accounts, BACS details, black/whitelists and also encode the tags before distribution. This latter function is facilitated via a PREMID communicator (central unit plus antenna) connected to the TATC. The customer is sent a monthly summary statement, which simply lists the total number of journeys by each user, although it is possible to obtain a fully itemised statement.

Operational Experience. Crosstalk between adjacent lanes does occur. Microwaves are reflected off high-sided vehicles, resulting in two AVI transactions being registered for the same user and at the same time - but on different lanes. Filtering by the Plaza Computer ensures that the customer's account is only debited once. It is also possible for a cash paying customer to gain passage via a tag fitted in the windscreen of a vehicle behind. The lane equipment ensures that the account holder is only debited once and is able to proceed as normal. Due to the variety of vehicle shapes, this type of problem cannot be entirely eradicated on a toll plaza where queuing inevitably occurs.

Another operational problem encountered is that of *rogue* tags. These are transactions involving tags which are not registered in the database. The tag is encoded with an account number that is held in the whitelist as credit OK or low. Because the tag does not appear in the blacklist, the driver gains passage through the toll plaza. The task of checking tag validity is thus carried out by the PCS, where any rogue tags can be blacklisted to prevent future passage.

Inter-urban Road Pricing. A year after the launch of DART-Tag, HM Government issued a discussion document entitled "Paying for Better Motorways". The Green Paper concluded that electronic charging is one of the only viable options for introducing on existing roads. Application of an AVI system to the national inter-urban road network would obviously require a standard tag.

The Department of Transport (DOT) appear to favour a simple permit system, as already used in Switzerland, effectively introducing a motorway tax disc. Its major disadvantage, however, is that the charge would be unrelated to the amount of use and time (of day or week) when the permit was used. Another problem is that enforcement can only practically be achieved by manual means - just as with the existing tax disc.

DRIVE is the European Community's research and development programme into Advanced Transport Telematics (ATT). DRIVE I (1989-91) adopted a standard for ID tag frequencies, which were formally approved by the European Radio-communications Committee (ERC) in February 1991 as 5.795-5.805GHz for pan-European applications and 5.795-5.815GHz to meet specific local requirements.

A consortium has been formed within DRIVE II to work on the Automatic Debiting and Electronic Payments for Transport (ADEPT) project. Its aim is to use the results of the DRIVE I programme to develop the concept of using an intelligent transponder and smart-card for a multitude of Automatic Debiting Systems (ADS), electronic payment and other complimentary Road Transport Informatics (RTI) applications. Key issues being addressed include:

- Real-time parking guidance, booking and debiting (both on and off street) in Lisbon;
- Development of a congestion metering prototype;
- Multi-lane tolling and the associated enforcement technologies in West Sweden and Thessaloniki, Greece;
- Definition of a common communications architecture and protocol;
- Development of a central system architecture which links integrated RTI and payment services.

The ADEPT ID tag is in the form of an On Board Unit (OBU) featuring a Hitachi H8 micro-controller with connection to a smart-card for holding all user information and transaction data. Credit can be added to the smart-card using payment machines to be fitted at petrol stations and post offices. A CAN interface, as used in the automotive industry, allows for connection to dashboard peripherals like keyboards, displays and vehicle instruments.

Conclusion. Automatic vehicle identification using microwave semi-passive transponder tags is a proven technology, with installations at Dartford, Mersey and the Severn Crossing in this country alone. There is little doubt that an inter-urban road pricing system of some kind will be introduced in the UK, although not necessarily via electronic means. The ADEPT project takes this idea one step further, in developing a single multi-purpose smart-card/tag that provides for all transport payment needs, *i.e.* both urban and inter-urban use.