AMTECH®

Fax Transmission

To: dr. Fimfon Garfinkeo

Company:

Fax #: (617) 876-5999

From: Francois Larnec

Date: 4/10/95

Time:

You should receive 21 page(s) including this one.
If you do not receive all pages, please call 856-8000 ext: 8012

Message:

Please find requested info attached.

Best Regards,

Francois

AMTECH SYSTEMS CORPORATION
Manufacturing & Technology Division
8600 Jefferson Street NE
Albuquerque, New Mexico 87113
505-857-0715 Main Fax

AMTECH®
Technology a Generation Ahead

SECURED PATRON'S PRIVACY IN NEW ETTM AND ROAD PRICING APPLICATIONS

Amtech Corporation
17304 Preston Road, Building E-100
Dallas, TX 75252 USA
Phone (214) 733-6600 • Fax (214) 733-6699

ABSTRACT

Preserving patron privacy while performing highly reliable transactions at all traffic speeds and conditions represents a significant challenge in the design and implementation of road pricing systems. Most systems available today use data encryption for transaction security. However, the encryption methods employed by these systems leave a trail of information which can be used to trace a specific transaction to a specific patron. Amtech's DyniCash™ system, on the other hand, uses a patented data encryption scheme with ISO smart card technology to ensure reliable and secure transaction processing at high traffic speeds while providing patrons' complete transaction privacy.

1. INTRODUCTION

DyniCash™ combines Amtech's proven, high speed Dynicom® vehicle-roadside communication technology with the most advanced digital electronic payment technology. Dynicom® has been recently selected by the Union Internationale des Chemins de fer (UIC) as the standard for European rail electronic vehicle identification for its vehicle trackside communication and operates on the European high speed train at velocities of up to 400 Km/h. DyniCash™ has been developed with European high speed requirement in mind and is able to complete a full payment transaction at speed up to 300 Km/h. Each system component will be presented in this document together with a description of each phase of a payment transaction. Also, the high level security features which provide complete privacy to the patron and which make the system unique will be covered.

2. SYSTEM OUTLINE AND COMPONENTS

The system as described in Figure 1 consists of three main parts, the charging part, the paying part and the controlling part.

2.1. The Charging Part

The charging part is represented by the Roadside Charging Station (RCS) located above the lane on an overhead gantry or on the side of the lane. It consists of a single enclosure which fully integrates an RF antenna, an RF module, a logic board, a kryptor board and a power supply module. The RCS communicates via RF link to the paying part (IVU-SC) at either 2.45 GHz or 5.8 GHz frequency. The communication speed is 192 Kbps for uplink messages (RCS to IVU) and 192/384 Kbps for downlink messages.

2.2. The Paying Part

The paying part is represented by the In-Vehicle Unit (IVU) and the Smart Card (SC).

2.2.1. The In-Vehicle Unit (IVU)

The IVU is equipped with a keypad to set up parameters or to enter the user's pin code, a two-line display, a three-colour LED, a buzzer and a smart card interface.

The IVU is a passive tag which means that it does not transmit a signal itself. The short-range radio communication link is based on Amtech's well proven "modulated backscatter" technology which is preferred to an active technology for the following reasons:

- The reader alone controls the microwave signal characteristic (frequency, frequency stability, transmitted bandwidth, power),
- The system is "frequency agile" in that IVUs track reader frequency,
- Many IVUs can be located in a small area (IVUs do not transmit),
- The bandwidth of receiver can be tightly controlled which reduces noise and increases performance,
- As the signal decreases more rapidly than in conventional radio system it is easier to control the reading zone,
- Both time division and frequency division multiplexing can be used.

2.2.2. The Smart Card (SC)

The smart card is ISO compliant and has two operating speeds, a normal speed at 10.752 Kbps and a high speed at 125 Kbps to allow fast payment transactions at a gate. The smart card offers two operating modes, post-paid or anonymous prepaid.

2.3. The Controlling Part

The controlling part is represented by the Plaza Computer (PZC) and the lane controller. The plaza computer controls all RCS on a toll plaza and communicates with a central computer. The lane controller handles lane devices such as light signals, enforcement camera and so forth.

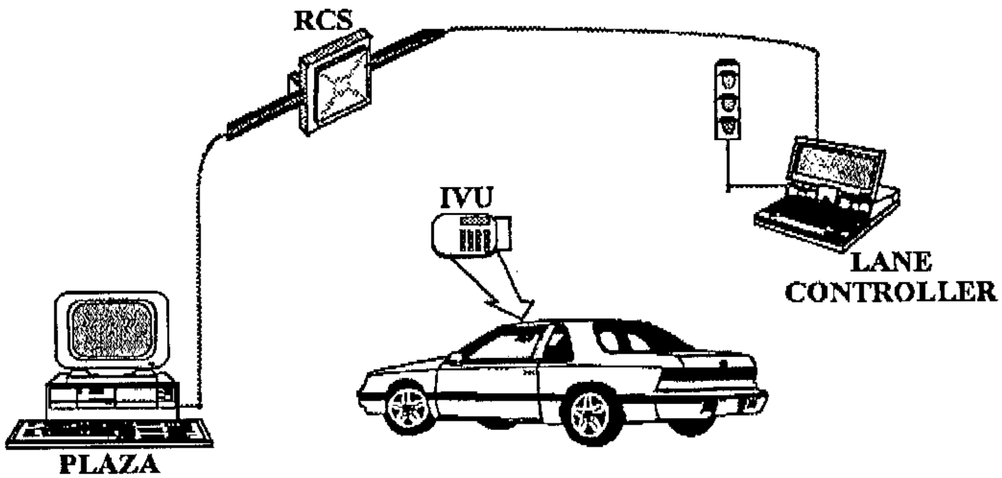


Figure 1 - System outline and components

3. TRANSACTION PHASES

An RF transaction between RCS and IVU consists of 4 phases (2 uplink messages and 2 downlink messages). The sequence is different depending on the system configuration, i.e. open/closed or prepaid/post-paid. Figure 2 describes the sequence related to a closed system under prepaid mode.

As soon as the IVU enters an RF field and the RF signal power reaches a threshold value, the IVU wakes up and starts scrolling its 'commit' message which includes information such as transaction number, vehicle classification, payment mode and others. At the entry gate, the RCS sends a 'get ticket' message which includes the answer to the authentication request by the IVU and gate information such as RCS identification code, time and date of transaction. The IVU acknowledges the message and the RCS ends the transaction with a 'hush' command requesting the IVU to stop modulating.

At the exit gate, the IVU's 'commit' message also includes the entry gate information stored at the entry. This allows the RCS to calculate the fare based on the vehicle classification, the route and the time. The fare is sent by the RCS to the IVU in the 'challenge' message together with challenge data which will allow the security scheme designed to protect each party involves not only the IVU and the RCS but all facets of the system.

4.1. Protection of Patrons

The patron wants to be sure that he is correctly charged by a valid toll-collector, i.e. balance correctly decreased by the proper amount and charging equipment (RCS) is legitimate.

The IVU/Smart Card authenticate the RCS by sending a random number to the RCS in the first 'commit' message. The RCS carries out a DES encryption on that random number using a secret key and sends the result in the next downlink message to the IVU. The IVU compares the received result with its pre-calculated result. If the results match, the transaction continues.

Moreover, transactions are stored in the smart card and can be displayed by the IVU at patron's convenience so as to allow him to check the validity of the amount paid. A receipt number also stored in the smart card may be used by the patron in case of claim.

Finally, the use of a PIN code changeable by the user prevents fraudulent use of the card.

4.2. Protection of Toll Charging Operators

The toll charging operator wants to be sure of the legitimacy of a patron's equipment (smart card) and of the correctness of a payment message (unaltered information).

The RCS authenticates the smart card by sending challenge data to the IVU in the 'challenge' message. The smart card pre-computes a table ('preparation matrix') before an actual transaction because encryption processes are time consuming and thus not compatible with time-limited road pricing applications (overall transaction time of 17 ms). The challenge digits are used by the smart card to pick numbers out of its table. Those numbers are sent to the RCS in the 'challenge' message and used by the RCS to both authenticate the smart card and to reconstruct the digital check.

Moreover, in case of closed system configuration (entry/exit) with entry data stored in the IVU, sent to the exit RCS and processed by this last RCS to calculate the fare, there is the possibility of having entry data altered by a defrauder so as to reduce the amount to be paid at the exit. This is why entry information is encrypted by the entry RCS using a secret key unknown by the user's equipment (IVU/smart card). At the exit, the RCS can check the validity of the entry information received from the IVU before it calculates the fare to be paid.

5. PRIVACY

The privacy of the patron is a widespread requirement although not always easy to achieve depending on the configuration of the toll system itself. With many parties involved in a complete toll system using prepaid smart cards (toll charging operator, bank or financial institution, clearing house, patron), it may be possible to design a system such that no party can get enough information in order to trace a specific patron's transactions but it is much more difficult to design the system such that even in case of several parties combining information together, it still remains impossible to trace transactions. Amtech's DyniCash™ system based on a patented data encryption scheme provides the solution to a completely secure system offering absolute transaction privacy to patrons.

5.1. Smart Card Reloading

The patron may use an automatic reload station located for instance in a bank, a gas station or a grocery store. He inserts his toll smart card in the reload station, selects the amount to be credited and inserts either bank notes, coins or a bank credit card. The signature server located in a bank or other financial institution authenticates the smart card and initiates the balance increase process. Once the balance has been increased, the smart card generates random numbers similar in nature to cashier's blank checks (see figure 3). Those checks are then 'blinded' or masked by the smart card and sent to the signature server for certification. The signature server signs the checks, but while it knows it validates a specific patron's checks, it cannot know the actual check number (masked). The bank's signature process involves an asymmetrical algorithm (RSA) with the secret key located at the bank. The signed, blinded checks are sent back to the smart card which removes the mask or 'unblinds' the signed checks. The smart card which has now an updated balance and a batch of signed checks is ready for use.

5.2. Toll Payment

When an IVU goes through a toll-gate, the RCS requests the smart card to decrease its balance by the proper amount. The smart card decreases its internal balance and fills in a signed check with the amount and date/time of the transaction. Then, the IVU sends the check to the RCS which verifies the bank's signature. The signature verification also involves RSA algorithm with the public key stored in every RCS. If the signature is valid, the toll charging operator can deposit the check later to the bank. When a bank receives a check for deposit from a toll charging operator, it recognises its own signature on the check but can not correlate the check number to a specific patron since the check was blinded when signed.

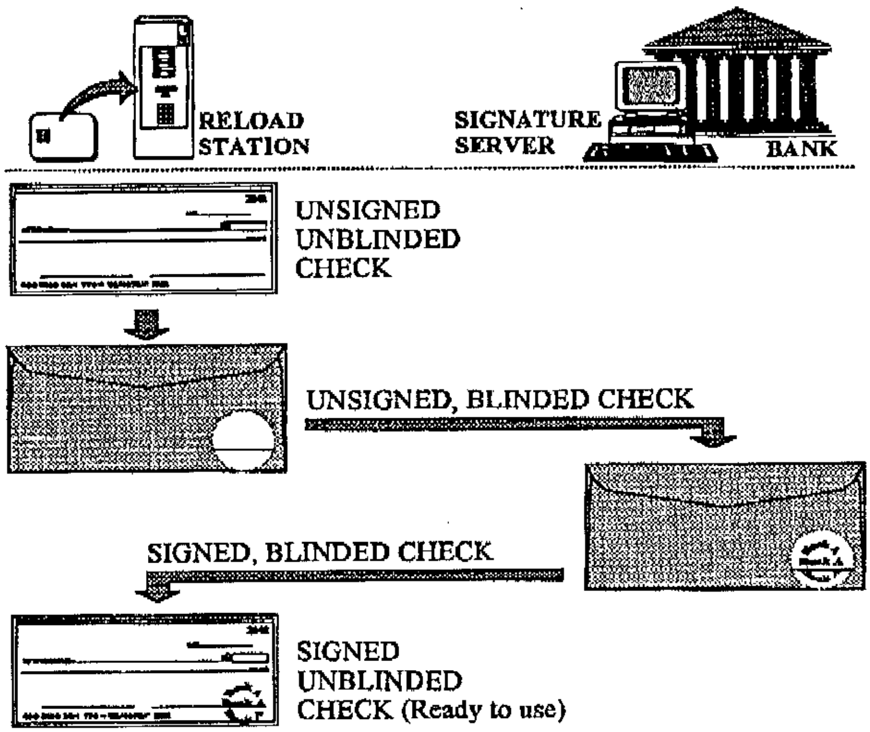


Figure 3 - Smart card reloading (digital checks)

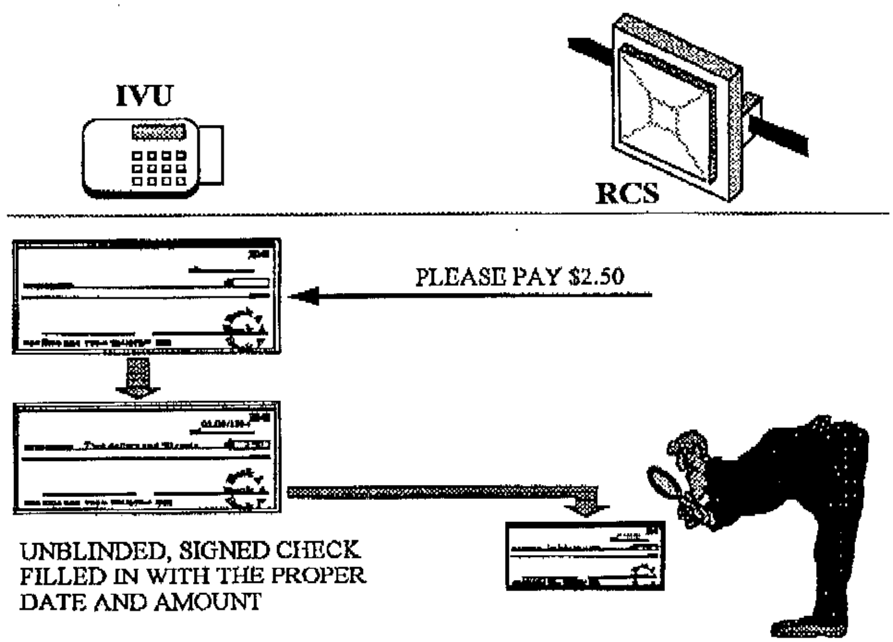


Figure 4 – Toll payment with digital check

6. FIELD TESTS

The system described in this document was tested under various conditions in Japan on February 26-27 and March 13-14, 1994. The test was organised and conducted by our Japanese partner, Mitsubishi Corporation, on a professional driving test course.

We tested the system under prepaid and post-paid mode, and open and close configuration. We used two interrogators located on an overhead gantry of 5 meters height and a lane controller connected to a traffic light and a video recorder in addition to the plaza computer.

We tested successfully the system under normal traffic condition, severe traffic conditions (bumper-to-bumper vehicles, two motorbikes side-by-side, two motorbikes side-by-side behind a large bus, heavy rain, snow on the windshield, ...) and high speed condition (up to 210 Km/h).

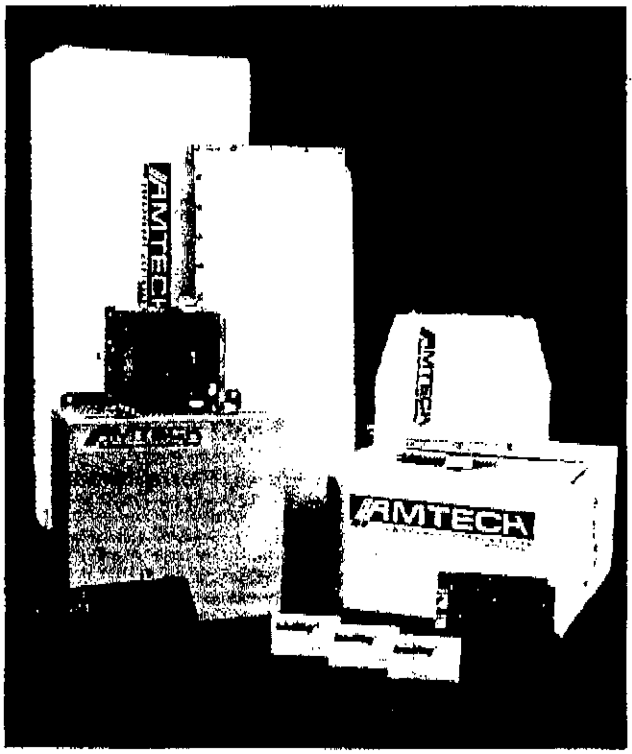
REFERENCES

[1] Scientific American, August 1992 : "Achieving Electronic Privacy" by David Chaum (David Chaum is head of the Cryptography Group at the Center for Mathematics and Computer Science -CWI- in Amsterdam. He is also founder of DigiCash, which develops electronic payment systems. Mr.Chaum received his Ph.D. in computer science from the University of California, Berkeley, in 1982 and joined CWI in 1984. He helped to found the International Association for Cryptologic Research and remains active on its board; he also consults internationally on cryptology.)

[2] Commission of the European Communities, R&D Programme Telematics Systems in the Area of Transport (DRIVE-ATT Project ADEPT), document # SD-002/WA100, January 25, 1993 : "Integrated Payment for Automatic Debiting Systems / Security: threat analysis and proposals for security algorithms"

[3] Commission of the European Communities, R&D Programme Telematics Systems in the Area of Transport (DRIVE-ATT Project ADEPT), document # UDN0024/WA100, March 16, 1993 : "Why do we need Public Key Cryptographic Solutions in the form of 'Slow and Fast Charge' in open Integrated Payment Systems for ADS ?"

IntelliTag™ Vehicle-Roadside Communication (VRC) System



System Components

Amtech's radio-frequency (RF) read/write IntelliTag™ system has two primary units: the on-vehicle unit, or "tag," and the roadside communicator unit (RCU). The RCU consists of an antenna, an RF transceiver (transmitter/receiver) module, and a read/write transaction processor (sometimes called a "reader").

Data processing devices may also be linked to the system, either at the roadside (in the form of lane controllers or auxiliary data processors) or via telecommunications (in the form of a central host computer) to a network of RCUs.

Additional secondary components may include vehicle presence detectors, modems and patron feedback devices.

How it Works

The IntelliTag system uses a principle called "modulated backscatter" to enable two-way vehicle-roadside communications (VRC). The backscatter tag is essentially a reflector; it does not generate or transmit a signal.

As a tagged vehicle approaches the RCU, a presence detector signals the system to turn on and the RCU sends out a single-frequency RF signal into the designated area termed the "capture zone." Inside the capture zone, the tag first enters the "read envelope," which is a large as the capture zone itself. The RF signal encounters the tag and is returned to the RCU antenna, along with the tag's identification (ID) and other data encoded in a simple modulation of the original RF signal.

The RCU decodes and validates the identified tag for use in this system and determines the data to be written back into this tag. Then the RCU begins to transmit the write command, addressed specifically to the tag just read.

As the tag enters the smaller "write envelope" within the read envelope, and the strength of the RF signal reaching the tag exceeds a preset threshold, a switch in the tag flips to permit the write transaction. The signal from the RCU is accepted by the tag and the new data is written into the tag's variable memory.

To confirm the transaction, the RCU then reads back the ID, along with the new data in the tag, and compares it with the message it sent.

The entire read/write/verify transaction takes place in only a fraction of a second.

The IntelliTag itself contains 240 bits of user-accessible data which may be configured by the system operator for storing fixed or variable data. Fixed data is information the system operator wants to keep with the tag. Vehicle ID or classification may be stored as fixed data. Such data is electronically locked during initial programming and cannot be changed except by the system operator with a security-enabled master programming unit.

The complete read/write/verify transaction takes place in only a fraction of a second.

Remaining bits designated for storing variable data will be accessible for reprogramming by properly authorized RCUs in the field during normal read/write operation.

AMTECH®
Technology a Generation Ahead

IT2000 TAGS

PRODUCT DESCRIPTION

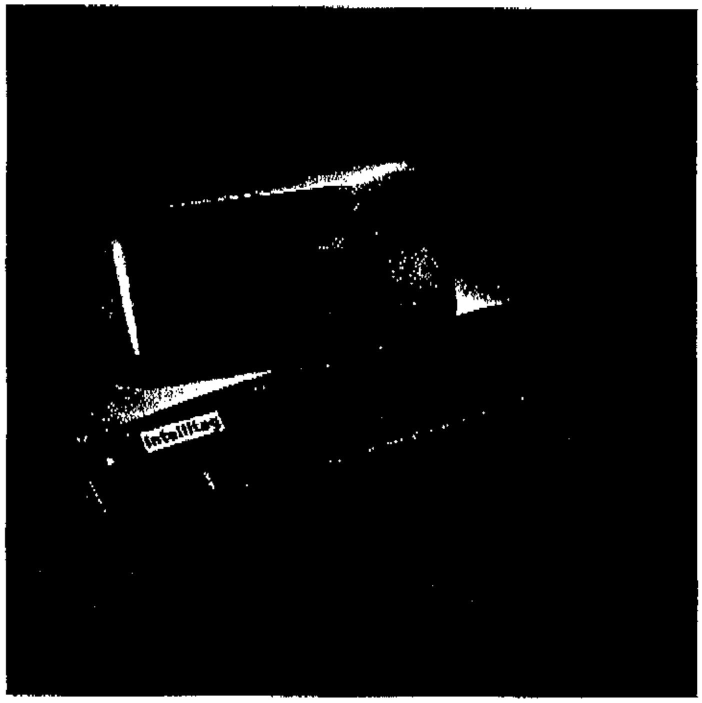
The IT2000™ tag is a small, self-contained, portable unit that provides wireless digital communication and memory for achieving information. In IVHS nomenclature, the tag is a vehicle-roadside communications (VRC) device capable of providing gateway communication at high speeds when passing within tens of meters of the reader. Intellitag Products has designed the IT2000 tag to perform reliable and secure communication for applications that include electronic toll collection, resource management, access control, driver information systems, and general VRC.

FREQUENCY AGILE TECHNOLOGY

The microprocessor-controlled IT2000 tags are RF-programmable and battery-powered. They use wireless, backscatter technology that responds to information from a roadside reader by reflecting and modulating the reader's RF signal. And they automatically adjust to and operate on any reader frequency within a broad band (eliminating the risk of obsolescence if the reader's frequency must be reallocated).

MOTOROLA PROCESSOR POWER

The tag features the powerful new ITC22000 mixed-mode signal processor family, specially designed by Motorola for IT2000 tags. The ITC22000 forms the basis for a product line of compatible and interoperable tags for wireless gateway communication. Its architecture is capable of addressing over a megabit of internal or external data memory. It offers multiple data rates for interoperability with other standards, extensive digital I/O to implement audio/visual indicators, on-board-computer links and smartcard access, as well as analog inputs for recording information such as temperature and fuel level.



THE

ONE TAG

THAT

DOES IT ALL

Intellitag products

A MOTOROLA/AMTECH technology partnership

THE URBAN TRANSPORTATION MONITOR

MAY 13, 1994

Roadside Beacons Used in Advanced Traffic Management Systems and IVHS

By Rand Brown, vice president of marketing, Intellitag Products

With every passing day, more travelers join the unorganized mass of vehicles using a limited number of highways. This increasing number of travelers all trying to reach a variety of destinations at the same time has been labeled "rush hour." Those using the nation's highways at these times simply call it a headache. Ask anyone who has ever traveled I-10 into Los Angeles, "When does the traffic subside?" The answer, most likely, will be "never." And in metropolitan areas, where major arteries used by commercial vehicles and commuters intersect, the need for efficient traffic flow has reached the critical point.

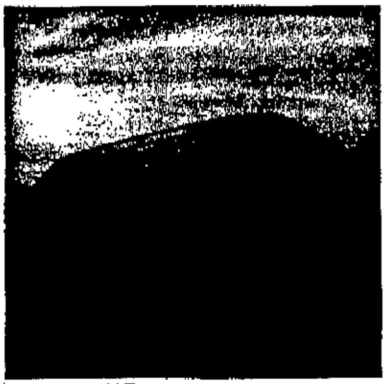
One way to improve the flow of traffic in major urban centers is to track and monitor vehicles with new vehicle-roadside communications (VRC) systems that provide two-way communications with vehicles. An advanced VRC system lays the foundation for most urban traffic plans. Specifically, advanced traffic management systems (ATMS), one of five intelligent vehicle-highway systems (IVHS) initiatives, have been implemented in specific areas, such as the federal and state highways in and around Houston.

Improving the Flow of Traffic

The roadside beacon and the technology behind its development will advance ATMS further into mainstream traffic management circles. A part of the future for IVHS, a roadside beacon is positioned in strategic locations along highways and thoroughfares. Depending on the complexity of the traffic patterns, readers can be deployed just at major intersections or at every entrance and exit along a road. Using a unique wireless technology, the reader sends signals that scan multiple lanes of traffic. The reader searches for specific tags, also called transponders, attached to vehicles traveling past at highway speeds. Because only 1-in-10 vehicles may have a tag attached to it, this type of ATMS is often referred to as managing traffic with probes. Monitoring 10% of the vehicles on a road can deliver an accurate representation of traffic patterns at a given time.

When the reader has identified the tags within its signal range, it completes communications with each one based on the information stored within the tag. The reader can gather useful information from the tags – such as vehicle or driver identification, the destination, origin, or the cargo – and relay that to a database in a traffic control center. Since privacy is an important issue, certain VRC systems provide tag security to keep private information from being read by unauthorized readers.

As vehicles move past one reader after another on a monitored highway, the data compiled allows authorities at a control center to assess the status of traffic flow. If it takes an inordinate amount of time for a tag to move from one reader to the next, the traffic control center will know an accident or other form of blockage has occurred and can identify where it happened. At that time, operators at the control center, whether municipal, state or federal authorities, can make emergency as well as traffic management decisions to assist all travelers.



Intellitag's IT2101 Tag

Advanced Technology Lends a Hand

Monitoring traffic is just the beginning of larger traffic management. The basic functions of urban area traffic management require read-only tags mounted in the vehicles. This kind of tag – used worldwide in non-stop electronic toll collection (ETC) and automatic vehicle identification (AVI) applications – simply transmits programmed data to the reader, which relays the information to the host computer.

Read-write communications is the next level for ATMS. With this method of communications, the reader is able to identify the tag from the programmed data and also "write" information into the tag based on the tag's individual identification. For example, as a reader identifies a particular tag, information such as the milepost number can be written in the tag. When the vehicle moves to another highway, readers in the same ATMS can identify from what location that vehicle arrived. This shared information allows traffic control centers in other urban areas to monitor traffic as it moves across boundaries. Obviously, the best situation for travelers would be to have one tag that is capable of both read-only and read-write communications with a roadside beacon. New VRC systems developed by Intellitag Products, the Motorola-Amtech partnership, provide tags with this capability by partitioning the available memory within the tag for a variety of applications. A universal communications tag, for example, could be used for ETC and gate access applications, which require read-only technology, as well as read-write applications such as advanced traffic management and a future IVHS application: advance traveler information systems (ATIS).

Traveling Down the High-Tech Highway

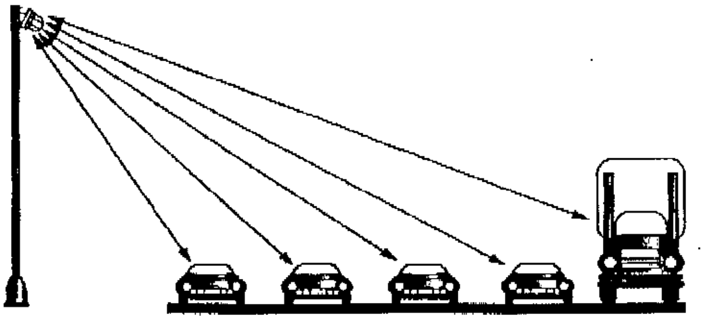
In addition to monitoring and tracking vehicles, a roadside beacon can be used in conjunction with a read-write tag to provide information to travelers as they move down the highway. Information travelers need, such as changes in speed limits to possible downroad detours, can be written into the tag and communicated to the driver.

Roadside beacons used in ATIS also will be able to deliver location information, such as approaching crossroads and exit points, as well as driver assistance information, including upcoming stops for food, fuel, lodging or government centers. For commercial vehicles, ATIS will increase efficiency by providing route guidance, improved trip planning and detailed, accurate messaging services. The result will be improved delivery time and increased productivity.

The roadside beacon can contribute to increased capacity, efficiency, safety and productivity of highway systems. With a decrease in travel time and hazards to the environment, and an increase in trip efficiency and emergency response, the guaranteed headache Los Angeles drivers get as they inch their way down I-10 will be a distant memory. Where travelers once dreaded making the long trip from one city to another, the information disseminated through roadside beacons will make trips quicker, more comfortable and convenient.

###

Rand Brown is vice president of marketing for Intellitag Products, the Motorola-Amtech technology partnership. He holds a VRC patent and has supervised the installation of more than 50 VRC systems in eight countries.



A roadside beacon, or reader, placed in a strategic location along a highway can identify moving vehicles containing tags. Readers manufactured by Intellitag Products, used in its vehicle-roadside communications (VCR) system, can identify vehicles and provide information to travelers on the highway through advanced traffic management.

AMTECH®

SELECTED AMTECH INSTALLATIONS

SUMMARY

October 1994

TYPES OF APPLICATIONS

Electronic Toll and Traffic Management

Airport Operations

Intermodal

Motor Freight/Fleet Management (U.S.)

Motor Freight/Fleet Management (Outside U.S.)

Rail

Security/Access Control

SELECTED AMTECH INSTALLATIONS

October 1994

Electronic Toll and Traffic Management Systems

Aberdeen Tunnel (also see "Cross Harbour" and "Lion Rock") **Hong Kong**

A pilot ETC installation by Amtech and Mitsubishi at the Aberdeen Tunnel in Hong Kong was launched in April 1992; pilot testing began in June 1992, and full-scale implementation began in August 1993. AutoPass Ltd., a joint venture with Cross Harbour Tunnel Co. Ltd. and Amtech, serves as a clearinghouse for customers to establish one account, with one tag, which can be used at three tunnels in Hong Kong.

By September 1993, about 20 percent of Aberdeen Tunnel's traffic used AutoPass, which is installed at four of the tunnel's 12 lanes. Total traffic at the Aberdeen, Cross Harbour and Lion Rock Tunnels is estimated at over 300,000 crossings per day, with approximately 80,000 AVI transactions occurring daily. As of September 1994, 42,000 AutoPass tags have been issued; 150,000 tags are expected to be distributed within the next few years. This system may also be expanded to other tunnels and car parks in Hong Kong.

Autopistas (Acesa/Aucat/Autema/Tabasa), Barcelona **Spain**

In joint projects with Amtech's international partners Elsydel and IBM, ETC systems were installed on the Barcelona Acesa Highway and the Tabasa Toll Tunnel in Spain in April 1990. The initial installation included four lanes at Acesa and two lanes at Tabasa. Contract extensions were awarded to IBM for additional lanes at Acesa, along with new implementations at Aucat and Autema, for a total of 70 lanes.

The Autopistas is the largest interagency ETC installation in Europe. A customer can use a single tag on all four tollways. Twelve of the lanes are "Presto" AVI dedicated lanes. Tag distribution totals 70,000; an estimated 100,000 tags is projected.

Caminos y Puentes Federales de Ingresos y Servicios Conexos (CAPUFE) **Mexico**

In April 1992, Amtech announced that Caminos y Puentes Federales de Ingresos y Servicios Conexos (CAPUFE), the federal toll administration for the Republic of Mexico, contracted to install 134 lanes of Amtech AVI equipment on approximately half of all existing toll lanes at 58 locations throughout Mexico. This installation spans nationwide, from Tijuana to the border of Guatemala, and required the coordination of efforts across numerous regional delegations. CAPUFE operates more toll collection points in Mexico than any other authority -- 14 toll roads and 32 bridges, handling over 13 million transactions a month.

Amtech teamed with Integra Ingeniera S.A. de C.V. of Mexico City to provide hardware and software for this automatic toll collection system. Components of the project included plaza computers and lane controllers, traffic control gates, and a vehicle classification system. Installation was completed in April 1993. Phase I was the distribution of 5,000 tags for CAPUFE-exempt vehicles. Phase II will be to tag commercial transportation vehicles. 100,000 tags are expected to be distributed by mid-1996. CAPUFE expects the system to improve the flow of traffic, especially around Mexico City.

Cofiroute **France**

Cofiroute is the only privately owned toll company in France. This heavily traveled highway, covering 730 kilometers (454 miles) in southwestern France, was equipped with 20 reader systems at two toll plazas near Tours. Amtech teamed with Sema Group on this installation, completed in May 1991 with 2,500 tags ordered.

Cofiroute is opening eight new lanes around Tours and is discontinuing its magnetic tollcard subscription in favor of electronic tags. Cofiroute is also considering the Amtech system for other Cofiroute highway projects in various parts of the world.

Crescent City Connection, New Orleans, Louisiana **USA**

In January 1989, Amtech installed its toll system on all 12 lanes of the Crescent City Connection spanning the Mississippi River at New Orleans for the Louisiana Department of Transportation and Development. The project was the first 100 percent implementation of AVI across all lanes. Three of the lanes on the bridge are dedicated tag-only lanes that include traffic control gates.

With Amtech's assistance, the Department implemented a TollTag Distribution Center in New Orleans. More than 34,000 tags have been issued by the Department as of June 1994. Of the 70,000 average daily transactions, more than 21,000 are AVI. During rush hour, 96 percent of tag users have used the dedicated lanes.

Regional multi-agency compatability allows these same tags to be used on the Lake Pontchartrain Causeway in New Orleans.

Cross Harbour Tunnel (also see "Aberdeen" and "Lion Rock") **Hong Kong**

Along with the Aberdeen Tunnel, the Cross Harbour Tunnel in Hong Kong began ETC operations in August 1993. Although they are independent operations, the Cross Harbour, Aberdeen, and Lion Rock Tunnels use the same AutoPass tag. Autopass Ltd., a joint venture with Cross Harbour Tunnel Co. Ltd. and Amtech, serves as a clearinghouse for customers to establish one account, with one tag, to use at the three tunnels.

ETC is installed at four of Cross Harbour Tunnel's 16 lanes, with an additional lane ready to be switched on when demand warrants. Total traffic at the Cross Harbour, Aberdeen and Lion Rock Tunnels is estimated at over 300,000 crossings per day, with approximately 80,000 AVI transactions occurring daily. As of September 1994, 42,000 AutoPass tags have been issued; 150,000 are expected to be distributed within the next few years. Expansion of tag use to other tunnels and car parks in Hong Kong is being considered.

Dallas North Tollway, Texas Turnpike Authority, Dallas, Texas **USA**

The Dallas North Tollway was the first toll road in the U.S. to incorporate ETTM. It is an excellent example of the benefits of Amtech's automatic toll collection system. The system was installed under a private/public-participation agreement (build/operate/transfer) between the Texas Turnpike Authority and Amtech. The project included design, manufacture, and installation of all host, plaza and lane computers, interface to existing equipment, and implementation of tag store operations.

On August 1, 1989, full implementation of ETC for 60 lanes (10 plaza computers) of the tollway was completed. Due to its enormous success, the Texas Turnpike Authority implemented four tag-only lanes as an added benefit for tag users in November 1990. After only two weeks of being in effect, more than 11,000 daily transactions were registered in just these four lanes. Amtech installed equipment for 28 more lanes, of which two are tag-only, constructed as part of a highway extension and opened in September 1994.

As of June 1994, more than 90,000 TollTags have been issued. An average of 85,000 AVI transactions out of nearly 300,000 occur each day. Patrons enjoy convenience, decreased traffic back-up, and shortened commuter time due to the Amtech system.

Esterel-Cote d'Azur Toll Agency (ESCOTA) **France**

ESCOTA serves as a major link to cities along the French Rivera for thousands of commuters each day and is the first truly commercial electronic toll collection system in Europe, implemented in January 1991. Amtech teamed with Elsydel to install 62 lanes on this 250 kilometer (155 miles) of highway near the city of Antibes in southern France.

Three of the lanes are "Presto" AVI dedicated lanes, and two lanes are AVI dedicated only (not high-speed). The remaining 57 lanes are "mixed" lanes. Average daily transactions total 360,000, with about 40,000 being AVI. About 45,000 tags have been distributed.

A unique benefit available to tag users is a direct interface with the national Minitel service, which enables users to directly check their balance accounts and current registered tag transactions, as well as request electronic funds transfers from their bank to tag accounts. Other tag-related operations, such as reporting stolen or lost tags, can also be directly transferred to the toll authority from the user's home terminal.

GA-400, Atlanta, Georgia **USA**

Lockheed IMS chose Amtech to provide ETC and closed circuit (CCTV) systems, and install a majority of the subsystems including vehicle classification and video enforcement systems, for 18 lanes of the Georgia Route 400 extension in Atlanta. Amtech also coordinated all the civil work activity associated with this project. Unique to this contract is the provision of a license plate-mounted tag. The installation opened in August 1993.

The Georgia Department of Transportation estimates 69,000 vehicles cross the plaza daily with about 15,500 AVI transactions. Administrators have stated that the system is exceeding all expectations, with average daily transactions as high as 80,000. Four lanes are designated AVI-only express lanes. As of June 1994, a total of 35,000 tags have been ordered for this installation and about 28,000 tags have been distributed.

Harris County Toll Road Authority (HCTRA), Texas **USA**

The Harris County Toll Road Authority (HCTRA) operates the Sam Houston Tollway and the Hardy Toll Road. Cubic Toll Systems chose Amtech for design, installation and integration, and maintenance training services to provide ETC systems for 69 lanes, interfacing with Cubic's existing lane equipment.

The HCTRA system was retrofitted to 31 existing toll plazas. Five main barrier plazas were designed to provide tag-only lanes located on the left-hand side in each direction, that allow for non-stop AVI transactions at speeds up to 50 mph. Amtech also provides system monitoring services.

Average daily transactions total 290,000, with about 30,000 AVI transactions. As of June 1994, over 26,000 of the 40,000 tags ordered were distributed. This system also accepts tags issued by the Oklahoma Turnpike Authority and the Texas Department of Transportation.

Lake Pontchartrain Causeway, New Orleans, Louisiana **USA**

Amtech's ETC system operates on the world's longest double-span bridge (42 kilometers or 26 miles) over Louisiana's Lake Pontchartrain in New Orleans. Six lanes were commissioned in December 1990. Two lanes on the bridge are dedicated AVI only during peak-hour traffic. The AVI system interfaces with the existing plaza computer and vehicle classification system.

More than 27,500 crossings are registered daily, and 15,600 of these are AVI transactions. Tag usage approaches 90 percent of total rush hour transactions. As of June 1994, more than 15,600 tags have been issued. Regional multi-agency compatibility allows these same tags to be used on the Crescent City Connection in New Orleans.

Lincoln Tunnel, Port Authority of New York and New Jersey **USA**

Amtech assisted SAIC in equipping the Lincoln Tunnel with an ETC system to collect tolls from buses for the Port Authority of New York and New Jersey. This is the longest continuously operating ETC system in the U.S., performing reliably and accurately in a very rigorous environment since April 1988.

Two dedicated bus-only lanes of the tunnel's 12 lanes are equipped with the ETC system and handle about 2,000 daily transactions. Approximately 3,100 buses are tagged. This system has significantly increased toll collection reliability and revenues.

Lion Rock Tunnel (also see "Aberdeen" and "Cross Harbour") **Hong Kong**

The Lion Rock Tunnel in Hong Kong began ETC operations in September 1994. Although they are independent operations, the Aberdeen, Cross Harbour and Lion Rock Tunnels use the same AutoPass tag. Autopass Ltd., a joint venture with Cross Harbour Tunnel Co. Ltd. and Amtech, serves as a clearinghouse for customers to establish one account, with one tag, to use at the three tunnels.

ETC is installed at three of Lion Rock's 13 lanes. Total traffic at the Aberdeen, Cross Harbour and Lion Rock Tunnels is estimated at over 300,000 crossings per day, with approximately 80,000 AVI transactions occurring daily. As of September 1994, 42,000 AutoPass tags have been issued; 150,000 are expected to be distributed within the next few years. Expansion of tag use to other tunnels and car parks in Hong Kong is being considered.

New York State Thruway, New York **USA**

The New York State Thruway Authority integrated a complete ETC system using Amtech AVI systems at six locations: Spring Valley, Tappan Zee Bridge, Buffalo Grand Island (north and south plazas), Harriman, and Yonkers.

Spring Valley implemented ETC on eight of its 16 lanes, and the Tappan Zee Bridge on all of its 13 lanes in August 1993. In October 1993, Grand Island Bridge implemented ETC on all 12 of its lanes at two toll plazas. Each location has two AVI-only lanes that can expand to four as demand increases. Two other plazas representing eight lanes at Harriman and Yonkers were recently added, for a grand total of 41 lanes associated with this project.

These facilities average approximately 169,000 daily transactions; about 68,000 are AVI-based. As of September 1994, about 87,000 tags were distributed. Tags issued by the E-ZPass Center can be used at any of the locations.

Oklahoma Turnpike Authority, Oklahoma **USA**

As the world's largest currently installed ETC project, this system covers 209 lanes on 940 kilometers (585 miles) of all 10 Oklahoma turnpikes. Constituting the PikePass system, the first 88 lanes were commissioned in January 1991, followed by another 97 lanes in September 1991. The remaining 24 lanes were equipped in March 1992. This state-of-the-art ETC system allows a PikePass user to continue on the turnpike at highway speeds while an overhead tag reader automatically records and bills or debits the account. Those who are not PikePass users must exit to complete a cash toll transaction.

This geographically broad installation required Amtech to design a system that would interface with a massive telephone communications network and remote plaza computers. A total of 21 plaza computers were installed. In addition to providing reader systems, auxiliary equipment, software, and maintenance services, Amtech opened and now operates PikePass retail offices in Tulsa and Oklahoma City.

Amtech lane controllers were later integrated with all the turnpikes' AVI, manual collection and automatic coin machine systems. Amtech also provided PikePass' video enforcement system. As of June 1994, 240,000 tags were distributed. Of the 160,000 average daily transactions, approximately 70,000 are AVI transactions.

San Juan-Rio Piedras Bridge, Puerto Rico **Puerto Rico**

SICE, a systems integrator from Spain, purchased and installed Amtech ETC systems for Dycrex, the contractor for a new private toll bridge that links the beach community of Rio Piedras with the airport in San Juan, Puerto Rico. Equipment for six lanes were provided and 10,000 tags initially ordered.

Severn River Bridge, Bristol **England**

The Severn Bridge spans the boundary between England and Wales. Cofiroute, a French-based agency, awarded this installation to Elsydel who selected Amtech for ETC and video monitoring systems. The installation was completed in October 1992.

Three of the eight lanes of the Severn Bridge are equipped with Amtech hardware and software. This bridge serves approximately 35,000 vehicles per day in each direction, with about 4,000 AVI transactions. Amtech software was developed for three classes of vehicles: cars, vans and trucks. As of June 1994, 8,000 tags have been shipped.

Societe des Autoroutes Paris Rhin Rhome (SAPRR) **France**

In November 1991, Amtech's marketing partner, Elsydel, installed an ETC system in Villefranche, France, on its Paris to Lyon route for the Societe des Autoroutes Paris Rhin Rhone (SAPRR). The initial SAPRR system, called SVT (Systeme Voies Telepeages), included four mixed AVI lanes (with the potential of up to several hundred), and one high-speed "Presto" AVI dedicated lane.

An extension of the system to the Genay toll plaza (also north of Lyon) with four AVI mixed lanes officially opened in October 1992. Daily AVI transactions total approximately 9,000. About 5,500 tags have been delivered to Elsydel, with 2,500 distributed to users to date.

Texas Department of Transportation **USA**

In May 1993, the Texas Department of Transportation awarded a contract to Amtech for an AVI system to monitor traffic conditions on three Houston freeways (I-10, I-45, and US-290). The project includes design, hardware, installation, and maintenance services, utilizing a large communications network and spread-spectrum radio. Amtech also supplied data collection and monitoring services.

This is the first application of AVI for electronic traffic monitoring on a congested highway system. Amtech AVI tags installed on vehicles serve as intelligent "probes" that relay information regarding highway traffic flow and travel times to a traffic management facility operated by the Texas Transportation Institute (TTI). With the data from the Amtech tags, TTI is able to assess travel conditions and provide motorist information regarding travel times and alternate routing advisories via variable message displays on the roadway or through local radio broadcasts.

Phase I of this installation, already installed and operating, covers 36 sites (161 lanes). Phase II covers an additional 52 sites (315 lanes) across five more highways, including the Hardy Toll Road.

As of February 1994, about 4,200 tags have been ordered for distribution to commuters. The system is now used in conjunction with tags issued through the Harris County Toll Road Authority, as well as other compatible tags from public and private entities.