MICROWAVE TAGGING AND APPLICATIONS

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This paper discusses the properties of microwaves and explains why they are a suitable transmission method for remote identification or *tagging* systems. The various implementations of microwave tagging technologies are reviewed, including the components that make up a typical system. Some of the established applications for microwave tags are described, as are developing and future uses for such devices.

Microwave Properties. The frequencies of microwaves are categorised into three major bands at the highest end of the Radio Frequency (RF) spectrum. They are as follows:

- Ultra-High Frequency (UHF): 0.3 to 3.0 GHz;
- Super-High Frequency (SHF): 3 to 30 GHz;
- Extra-High Frequency (EHF): 30 to 300 GHz.

Due to their close relative positions in the electomagnetic spectrum, it is hardly surprising that microwaves posess some of the properties of radio and TV waves in that they can penetrate both transparent and opaque non-metallic materials. Microwaves are thus well suited for operation in harsh environmental conditions. The strength of the microwave signal will be reduced or *attenuated* as it passes through contaminants (*e.g.* water, snow, ice or dirt), thereby limiting the achievable communication range.

Infrared and then visible light follow microwaves in the electromagnetic spectrum as we increase frequency. Microwaves therefore adopt some of the optical properties of light, with their ability to form well defined beams. This *spatial directivity* allows access zones to be established, *i.e.* well defined areas in which it is possible to accurately receive the microwave signal.

The characteristic electromagnetic resistance of microwaves means that long range communications are possible, even in noisy environments with strong electrical and magnetic fields. This property has particular significance for military applications such as radar (1).

Microwave Tagging Technology. All remote identification systems, including those based on microwave transmission, 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.

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. Most of the commercially available microwave tagging products rely on semi-passive technology (2).

Electronic Toll Collection (ETC). Cashless non-stop ETC is now a viable alternative to previous methods requiring the manual collection and/or processing of cash. This has been made possible via the use of microwave based tagging technology.

All implementations of non-stop cashless ETC rely on two major system components: a transponder and a communicator. The transponder is assigned to a customer and/or the customer's vehicle and replaces cash as the form of toll payment. The stationary communicator is used to remotely identify the moving transponder and therefore validate the customer's payment. It consists of an antenna (or antennae) connected to a Central Processing Unit (CPU). The positioning of the transponder depends on where the antennae are located. Figure 1 shows some typical arrangements employed by the major manufacturers.

The transponder comes in one of two forms: either a simple matchbox/credit card sized tag or an In-Vehicle Unit (IVU). Tags require no special installation procedure, whilst IVUs may require connection to the vehicle's electrical and electronic systems. Tags are also far cheaper to manufacture and offer greater flexibility to the customer, as they may be easily transferred between different vehicles.

There are three types of tag available: read-only, read/write and partitioned. Read-only tags contain fixed information, which is usually encoded during the manufacturing process. Although they are cheap, read-only tags offer the least flexibility to the operator as far as implementation is concerned. Read/write tags can be encoded by the operator and thus offer a greater level of flexibility in their use. This advantage has to be measured against the greatly increased unit cost and decreased operating range, especially during the write cycle. Finally, partitioned tags offer the greatest flexibility in that they enable multiple applications to be supported by the one tag, utilising a separate password protected memory partition for each application. Each partition may be designated read/write or read-only, making this form of tag the most expensive of the three (an important consideration in the mass market environment).

In its simplest form, an IVU may just be a tag with a built-in credit indication. Other IVUs incorporate smartcards in order to store credit. The smartcard may be removed by the driver on leaving the vehicle, so as to prevent theft and allow it to be used for other transport payment functions, *e.g.* car parking and public transport. This is becoming more important as integrated transport policies and strategies are being considered by road administrations throughout the world. More complex graphical displays and keyboards (for user input) can also be incorporated, if desired.

Depending upon which transponder is chosen, the technology can be implemented in a number of ways. Table I indicates the various transponder types and which implementation of ETC they are suited to.

Automatic Vehicle Identification (AVI) has been the choice of the three UK non-stop cashless ETC operators at Dartford, Mersey and the Severn Crossing, all of whom utilise read/write tags encoded with a unique identification number before distribution to the customer. Individual users can be blacklisted to prevent passage in the event of a tag being stolen, lost, misused or unpaid for. However, it is not possible to guarantee user anonymity with this system, which can prove unacceptable in certain environments - a notable example being Hong Kong.

With Automatic Debiting Systems (ADS) the transponder, be it a read/write tag or IVU, is used to store the balance of funds remaining. As the transponder is interrogated by the communicator, the current balance is read, the toll due deducted and a new balance is written to the transponder. User anonymity can therefore be maintained, the system effectively being similar in operation to a phonecard. Depending on the memory capacity of the transponder, it may also be possible to store the last 100 or so transactions in addition to the user's balance. A transaction is defined as a self-contained record detailing the location, time and date of the journey undertaken. The operator could then interrogate the transponder on the customer's behalf in order to obtain a list of those journeys undertaken using the ADS transponder.

Hybrid systems utilise partitioned memory tags or IVUs to offer both AVI and ADS facilities to the customer. This raises the possibility of compatibility between different operators, despite employing different implementations of ETC. The same transponder can be used as payment at various tolled locations. Agreement would have to be sought between the companies involved before offering such a scheme. It would also require the use of one manufacturer's ETC equipment across all the sites, as there are no established national, inter-national or industry standards for the communications link between transponder and communicator as yet.

Road Transport Informatics (RTI) applications may utilise an IVU to provide in-vehicle real-time information services. These systems can incorporate ETC alongside the other facilities, but again require a common communication link between the transponder and communicator to achieve this goal. Nevertheless, this area must be seen as the future for implementing ETC (3).

Table I - Transponder types and their implementation of ETC

	AVI	ADS	Hybrid	RTI
Read-only	Yes	No	No	No
Read/write	Yes	Yes	No	No
Partitioned	Yes	Yes	Yes	No
IVU	Yes	Yes	Yes	Yes

<u>Access Control</u>. By linking a communicator to a motorised barrier or electromagnetic lock mechanism, access control systems automatically open/unlock doors when only valid recognised tags enter the microwave antenna's access zone. Movements of authorised personnel or vehicles (AVI) can be logged by a central computer for future reference.

Hybrid systems normally use the same tag for vehicle and driver. In addition to the obvious cost benefit (one tag instead of two), this system also has the advantage of preventing stolen vehicles from entering and leaving a restricted area. An alternative approach is to equip the vehicle with an IVU, which only operates when a combined ID/smartcard is inserted. The smartcard doubles as a security pass, because it bears the holder's photograph, but it can also be used for more traditional card entry access control (cheaper than remote tagging). If both the central computer and smartcard hold details of movements, this raises the possibility of on-the-spot checks by security personnel using portable battery-operated smartcard readers.

<u>Container ID</u>. Automatic remote identification of containers is already widely used by railway and port authorities. Read/write tags can be either fixed onto or built into the containers and encoded with details of contents, intended destination, journey route, plus any special handling precautions. This information can be read by fixed communicators on entry to the port and/or by mobile communicators on gantry cranes. The latter method allows for an automatic computer-based positioning system, which helps in optimising the use of space, equipment and manpower - ultimately resulting in reduced costs and increased profit for the port authority (4).

<u>Baggage ID</u>. A developing application for microwave tagging is that of automatic identification of airline baggage. Tags are passive and, by keeping most of the electronics in the communicator (rather than on the tag), they can be manufactured inexpensively enough to enable airlines to use them on a disposable basis. The tag is encoded at the check-in desk with a unique number. It is subsequently read using a communicator which features a portal antenna large enough to accommodate standard conveyor belt baggage handling systems (5).

Factory Automation. Production lines on factory floors have long been automated via the use of microwave "memo" tags. A read/write tag is encoded with the custom details for a particular order and this is then attached to the product. Communicators can be linked to intelligent machinery for automatic operation, *e.g.* desired product colour is read from tag and paint spraying begins. Operations requiring manual activity can also benefit from increased efficiency by the appropriate manufacturing details being read from the tag and displayed on a screen for the factory worker to carry out. It is interesting to note that the Programmable REMote IDentification system (PREMID) was developed by Philips from an automotive factory system into the AVI system used throughout the world today (6).

ADEPT. The Automatic Debiting and Electronic Payments for Transport (ADEPT) project is part of a European Union reasearch and development programme into Advanced Transport Telematics (ATT) or RTI. Its aim is to develop the concept of using an intelligent microwave based transponder and smartcard for a multitude of automatic debiting, electronic payment and other complimentary RTI applications.

Key issues being addressed include real-time parking guidance, booking and debiting (both on and off street). This would allow a driver to book a parking place in his/her intended destination whilst driving there. The on-board display would guide the customer to the car park and the fee would be automatically debited from the smart-card. Extra credit could be bought at petrol stations and post offices. This trial is taking place in Lisbon.

The same smart-card could be debited when a driver hits a traffic jam, the charge being related to the severity of the congestion. Public trials of such a congestion metering prototype in Cambridge have been completed, although technical evaluation of the equipment is continuing in both Cambridge and Newcastle.

The problems associated with multi-lane tolling and its enforcement technologies are being addressed in Sweden and Greece. As a result of the Swedish trials in Göteborg, their National Road Administration is due to implement a toll ring around Stockholm by Autumn 1997. The Greek trial in Thessaloniki was launched in March 1994 and was completed by the year's end.

ADEPT is defining a common communications architecture and protocol for equipment used with the system. Development of a central system architecture linking payment services with integrated Road Transport Informatics is also taking place (7).

ADEPT is ongoing, but some conclusions have already been reached:

- The feasibility of using a bi-directional 5.8GHz microwave link with a high data rate has been proved for high-speed vehicle to roadside communications applications.
- ADEPT has proved that multi-lane tolling and road-pricing is technically feasible.
- Current International Standards Organisation (ISO) specified smartcards appear to be too slow for use in high-speed cashless ETC. A transport-specific smartcard will need developing which offers a higher read-write speed than the current standard.
- Mono-lane video enforcement has been proven and a full multi-lane enforcement system is planned for the Göteborg test-site. This will be the first working demonstration in the world of multi-lane debiting and enforcement using a 5.8GHz automatic debiting system. However, the issue of cross-border management has yet to be addressed (8).

Conclusion. Microwaves are clearly suited to communicating over long ranges and in harsh environments. The majority of tagging systems which use microwave transmission methods are based on passive or semi-passive technology. Microwave tagging can be employed in high speed applications which feature a large data flow.

References

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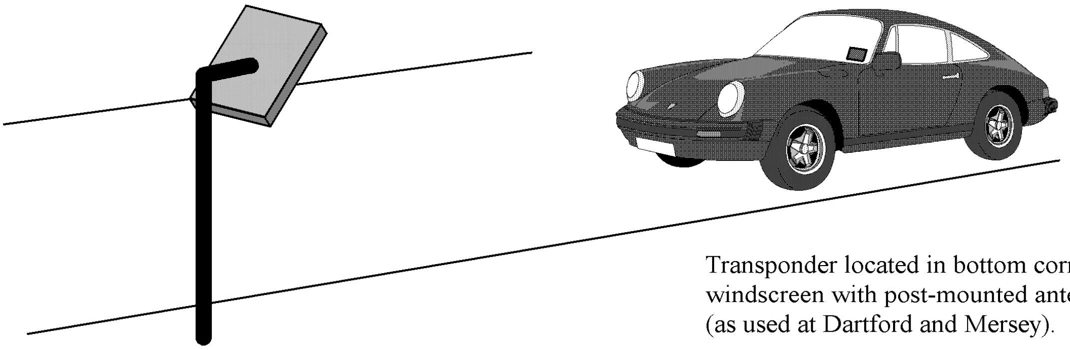
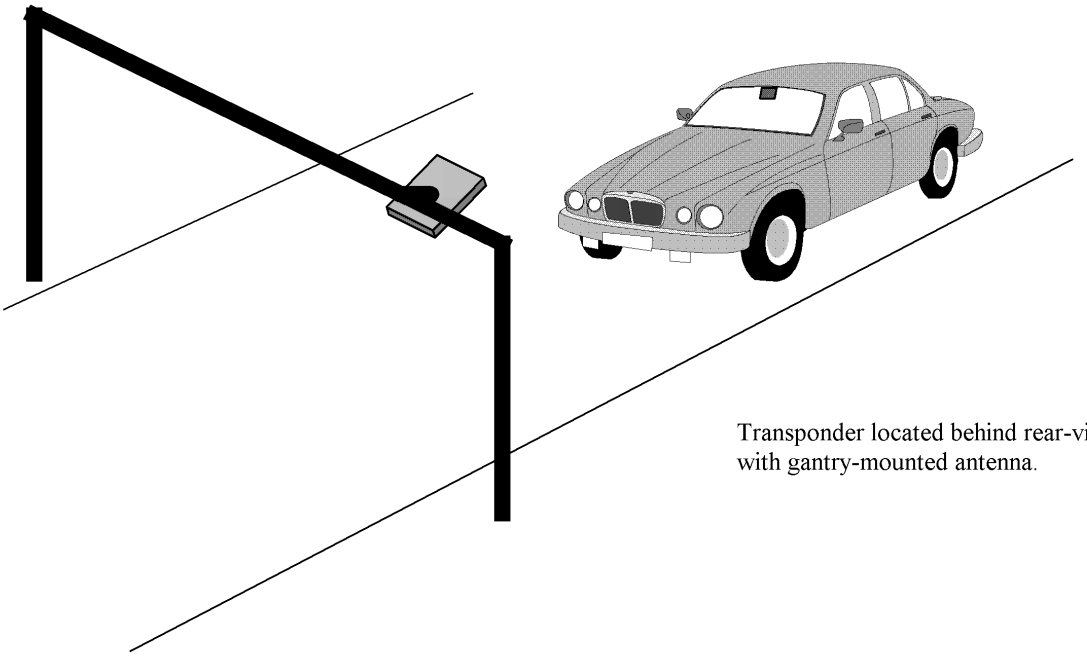
7. See 3.
8. Prof. P.J. Hills, Transport Operations Research Group, University of Newcastle.

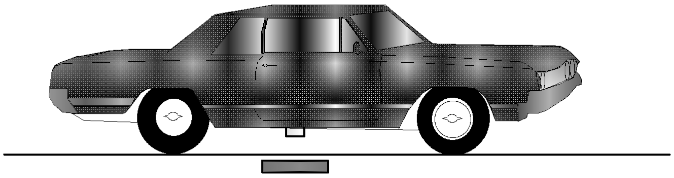
Figure 1 - Typical transponder and antenna arrangements



Transponder located in bottom corner of windscreen with post-mounted antenna (as used at Dartford and Mersey).



Transponder located behind rear-view mirror with gantry-mounted antenna.



Transponder located underneath vehicle with antenna buried in road surface.