THE USE OF MICROWAVES IN EUROPE TO DETECT, CLASSIFY AND COMMUNICATE WITH VEHICLES

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ABSTRACT

Microwave techniques have an important role to play in developing the communication infrastructure for control and management of road traffic. They are also used in stand alone systems to improve driver safety and for speed enforcement. Road traffic engineers could use a portable microwave system to obtain traffic statistics to help plan new roads. The paper below briefly describes some of these applications.

INTRODUCTION

Road traffic congestion is becoming a serious problem worldwide. Not only does it affect the environmemt, causing increased air and noise pollution, but the cost of lost time and fuel is a major loss. It has been estimated that the cost of congestion in Europe is 500 billion ECUs or about 700 billion dollars per annum.

In Europe there is an initiative called DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) which states in its workplan that "it is no longer economic to continue to increase the capacity of road systems by building more roads". An alternative is to control and assist the traffic using Road Traffic Informatics (RTI) systems of Intelligent Vehicle/Highway Systems (IVHS). These include route guidance, road pricing, incident detection and many more facilities designed to ease the path of the driver and increase the capacity of the existing structures whilse also making travelling safer.

DETECTION

Anticollision Radar

One approach to increased driver safety and reduction of accidents is the anticollision radar which would be particularly useful in fog or rain. In Europe, since the maximum speed of cars is about 130 km/h, a maximum target range of 100m is required so that vehicles can stop in time.

Frequencies of 35GHz and above are used to make the size of the antenna practical for installation in a vehicle. A summary chart of existing (anticollision radar) systems is given in Fig.1.

Horizontally the radar beam needs to be confined to one line or about 3.5m, whilst in the vertical plane it must not reflect from overhead bridges, usually about 6m high. An antenna aperture of about 2.5 degrees horizontally and 3.5 degrees vertically is generally satisfactory. As part of the PROMETHEUS program [1] AEG in Germany developed radars at 35, 60 and 90GHz with a maximum range of 200m. The final design will depend upon the allocated frequency band which is expected to be 76 to 77 GHz.

Multipath reflections occur causing fading nulls in the received signal as the direct path signal interferes with that reflected from the road. This problem can be alleviated by increasing the transmitter power. A radar operating at 35GHz requires an extra 6 to 8dB to obtain the same power specification as a system working in a non-multipath environment [2].

Pulsed or FMCW (Frequency Modulated Continuous Wave) systems are used to detect distance, speed and acceleration of a target. If the target is too close a warning is given to the driver to take action. (Automatic braking is considered too dangerous.) Pulsed modulation gives better discrimination in multitarget environments but an FMCW system is cheaper. Cost is an important consideration which implies that the in vehicle unit should use a MMIC approach for high volume, low cost production.

Vulnerable Road Users

Some groups are directing their attention towards pedestrians and cyclists - the vulnerable road users.

A pilot test has been carried out in Bradford [3] to make crossing the road safer and quicker. Previously, at a four-way junction pedestrians had to cross the road during a 1s all-red period in the traffic light cycle. An X-band microwave detector placed on top of the traffic light and directed towards the pavement was used to detect approaching pedestrians causing the all-red period to be increased to 3s. Fig.2 shows the detector in use. In a second experiment a similar detector was positioned to oversee the approach to a pelican crossing. Detection of an approaching pedestrian pre-activated the push button signal to reduce the delay.

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The detectors proved both reliable and durable. Over 80% of approaching pedestrians were detected with some false alarms being recorded when large vehicles were driven close to the pavement. Worries that the microwave unit would be vandalised proved unfounded and the units were not affected by adverse weather conditions.

The pilot test proved that the microwave detectors would detect pedestrians and could endure 'on-street' conditions. No increase in red light violations was observed and more pedestrians crossed during the 'safe' period.

COMMUNICATING WITH VEHICLES

Efficient road pricing schemes need Automatic Debiting Systems (ADS) to reduce delay times at payment points.

Telepass is an ADS installed along the Milan-Naples motorway in Italy. Fig.3 is a picture of the Toll Plaza. Communication over a 5.72GHz link is between a roadside antenna and a transponder in the vehicle. A SMART card is inserted into the transponder for pre-payment or direct debit from a bank account. Vehicles have to slow down to 50km/h and if communication cannot be achieved the driver is directed towards the cash payment lane. Violations are recorded on film.

Another system has been developed under the PAMELA (Pricing And Monitoring Electronically of Automobiles) project [3], which seeks a pan-European debiting system for use in non-stop tolling and car-parking. The roadside beacon, usually mounted on an overhead gantry, communicates with a small, passive transponder in the vehicle via a modulated microwave carrier at 5.8GHz. A Patch antenna of 4 x 4 elements with 17dB gain and 20 degrees beamwidth is mounted about 5.5m above the road at an angle of 20 degrees to the vertical directed towards the vehicle antenna which has a 120 degree beamwidth. Circular polarisation is used to obtain some discrimination against reflections. A diagram of the system is given in Fig.4.

The system has been tested on an unopened stretch of motorway near Newcastle, UK with speeds up to 50km/h. Possible obscuration of the transponder by taller vehicles had little observed effect and single lane discrimination was achieved. The system is intended to operate at traffic speeds up to 160km/h and further trials are under way.

SMILER (Short range Microwave Links for European Roads) is another DRIVE project [4] to develop a short range broadband communication link between a radar traffic acquisition sensor and vehicles. In the first stage it is unidirectional but further development is envisaged for a bidirectional link.

Communication occurs at 61GHz between a beacon with a 3dB beamwidth of 3 degrees vertically and 13 degrees horizontally mounted on a footbridge and the unit on the roof of the vehicle which has a 20 degree beamwidth. The beacon is shown in Fig.5. The horn antennas are aligned at an angle of 53 degrees relative to the lane. The antenna is mounted external to the vehicle to reduce attenuation. At 5.7GHz the attenuation caused by a windscreen has been measured [5] as 2 to 6dB, whilst rain and windscreen wipers can cause 10 to 15dB attenuation. As well as transmitting data, the system uses the Doppler shift on the signal to log the speed of the vehicle.

The system was tested on vehicles travelling up to 145km/h. Single lane discrimination was achieved with no interference from other vehicles in the same lane. Although the prototype equipment is in waveguide, future models will be build using monolithic technology for lower cost and higher volume production.

CLASSIFICATION

Inductive loops in conjunction with axle detectors can separate traffic into 21 different classes but they are susceptible to damage from tarmac subsidence and utility companies. A microwave system which was non-invasive and easily portable has been developed in conjunction with Sense and Vision Electronic Systems Ltd. [6]. It can automatically classify cars, light goods, medium goods, heavy goods and buses to an accuracy of about 75%.

An FMCW signal at 10.5GHz is reflected from the target vehicle. Digital signal processing derives a microwave profile of the target from speed and range data, which is then classified into one of the five groups. A 10" dish antenna with a 3dB beamwidth of 10 degrees provides single lane discrimination when mounted on an overhead gantry at an angle of 45 degrees to the vertical.

The system is in the early stages of development and future work is expected to improve the classification accuracy to over 90%.

CONCLUSIONS

Microwave systems are taking a significant part in the design of RTI systems developed to increase the safety of drivers and ease their journey by broadcasting information on potential hold-ups and reducing delays during payment. One possibility which should not be ignored is the potential of combining system functions. The classification system could be used in conjunction with ADS to detect fraud and with traffic information systems to gather statistics of road use, for example.

REFERENCES

[1] Prometheus, WGI. 'Topics of Research'. Nov.1987.

[2] Alvisi M, et al. 'Anticollision Radar: State of the Art'. Proc. DRIVE Conference, Feb.1991, pp.943-961.

[3] Blythe P T et al. 'A Short-range Road to Vehicle Microwave Communications Link for Automatic Debiting and Other RTI Services'. Proc. DRIVE Conference, Feb.1991, pp.248-268.

[4] Boheim, Fischer H J, 'A 61GHz Link: Potentiality, Feasibility, Results'. Proc. DRIVE Conference, Feb.1991, pp.174-193.

[5] Baranowski S, Lienard M, Degauque P. 'Beacon-Vehicle Link in the 1-10GHz Frequency Range'. Proc. DRIVE Conference. Feb.1991, pp.194-217.

[6] Hobson G S, Roe H, Hawley J P. 'Microwave Classification of Road Vehicles'. Proc. 20th European Microwave Conference, Vol.2, Sept.1991, pp.996-1001.

Fig.2: The Microwave Detectors in use at a Junction.

Firm / Charact.	AEG	Auto-stop	Bendix	GM	Lucas	Munich T.Univ	Nissan	RCA	RCS	SEL	Sperry	Toyota	TRW	VDO	Rashid
Automatic / Cooper.	N N	A N	A N	A/N N	A N	N N	N N	A C/N	N N	N N	N N		A N	N N	N
Frequency GHz	35 60 90	10,5	22,1 36	8-12	32,6	94 imaging	24	10,5 17,5	33,4	35	1,75	50		9,3 35	24,25
Power mW	300	50	25		25	200	20	27	5	20		30		200	20
Modulation	P 20ns FM	2 F	2F	P 1ns	FM	P 1ns	P 20ns	FM	2 F	FM		FM		P 30ns	FM
Nr of antennas	2	2	1	2	2	1 scan	1	2printed	1	1	3	2		2	1
Gain of antenna dB		25	30		25			25	32			32		22	
Aperture (°) H V	2,5 3,6	5,5	2,5 4,5		5	1,5/360 20	3,5 4	3 5	4	2,5 3,5	eq.2,5	2,5 4	2,5	2,5 4	
Maximum range m	120±5 200	100	45 100		100	50 ±0,015	100	30 50	100	100 ±2,5/5	45	60	30	120 ±0,5 200	120
Price $		350	200						875	1500	low		288?	875	558
Country	FRG	USA	USA	USA	GB	FRG	J	USA	USA	FRG	USA	J	USA	FRG	USA
N° Ref. Literature Survey	4;22; 135;201	15;29; 33	15;29; 33	29;136;	15;33	48	28; 187	15;33	15;29 ;33	4;10 198	97	166	19; 29	4;15; 29;33	292-4 308

Fig.1: Existing Anticollision Radar Systems.

Fig.3: Telepass.

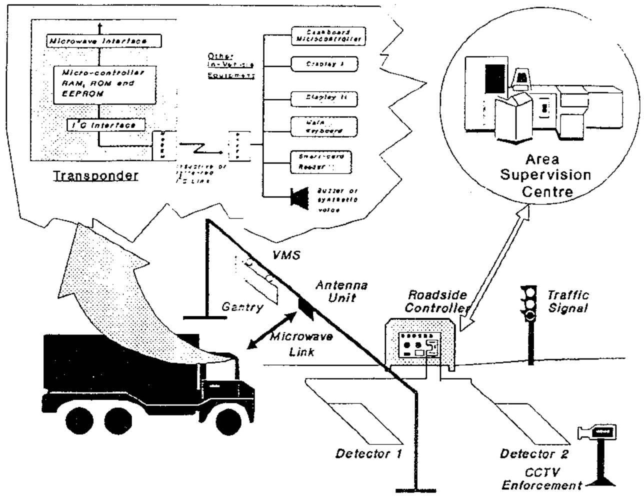

Fig.4: Arrangement of the PAMELA Equipment.

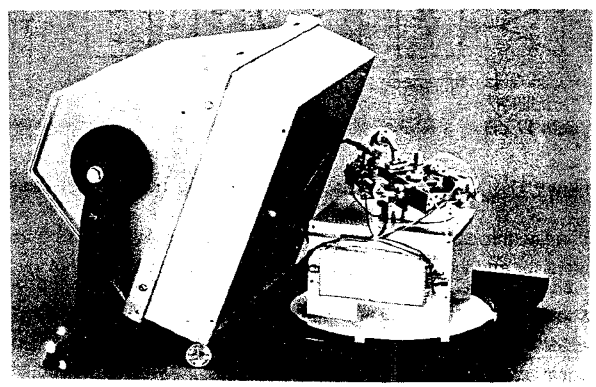

Fig.5: The SMILER Beacon.