SHORT RANGE MICROWAVE LINKS FOR TRAFFIC AND TRANSPORT APPLICATIONS

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Abstract

Short range microwave communication links in traffic and transport may be used for automatic debiting, navigational aid, collision avoidance and traffic flow improvements.

Some examples of existing systems are presented. A review of the future requirements is also given illustrated by presentations of some experimental systems in the frequency range 2.4 - 60 GHz which are being studied in Europe.

Introduction

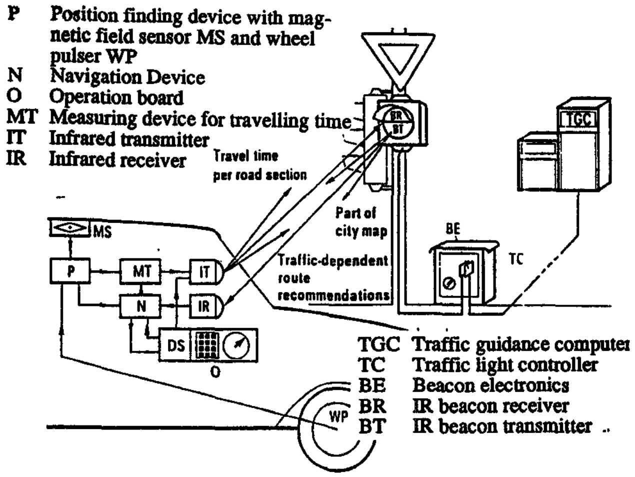
The growth of road traffic leads to problems such as e.g. increasing number of accidents, reduced efficiency and environmental effects. Short range communication links with range below 300 m between vehicles and between vehicles and the roadside are essential for implementation of new concepts aiming at improving existing traffic systems.

The intent of this paper is to give a perspective of short range microwave communication links in present and future traffic applications.

SHORT RANGE LINKS TODAY

Route guidance systems

Systems for interactive route guidance are now being tested in some large European cities. Beacons located on traffic lights transmit navigation and route guidance data to on board receivers. Communication in the reverse direction is used for collecting traffic data. Current implementations are based on infrared. An example is the experimental interactive route guidance system installed in Berlin (LISB). The data rate for this system is 125 kbit/s in both directions. Under favorable weather conditions the range is above 50 m.



Example of Route Guidance System based on IR

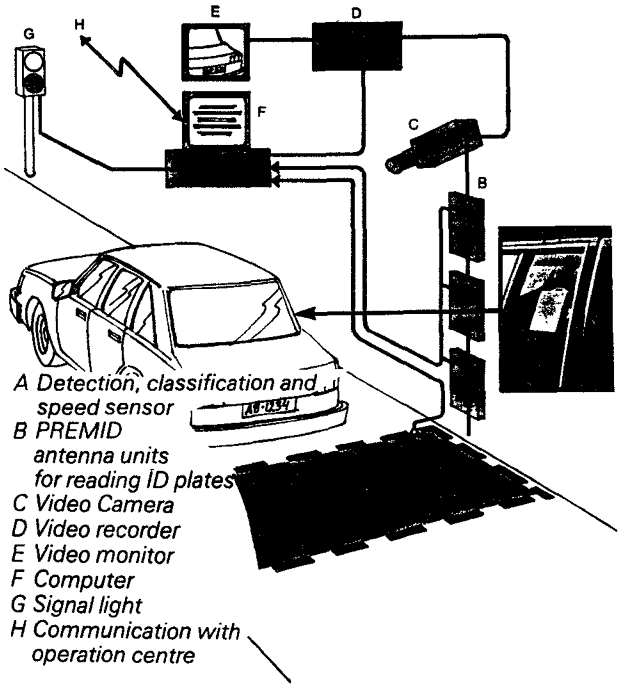
Debiting systems

Several test installations of automatic debiting systems for roads and tunnels have been installed. Two types of implementations are being considered. One alternative is to use identification techniques. When a vehicle is passing a debiting station an unique identification code is received from the vehicle. A bank account linked to the identification code is then automatically charged by the system. A unidirectional link can provide the requested data transfer. This type of link is also in commercial use for automatic container identification.

A second alternative is based on the use of a smart card in the vehicle. The card contains a prepaid cash value. The payment is made anonymously. A bidirectional link is required.

Existing microwave systems use transponders in the vehicle. The transceiver interrogates the transponder by illuminating it with a single frequency signal. This signal is reflected in the transponder and then received by the transceiver. The data transfer from the transponder is accomplished by modulating the reflection coefficient in the transponder. The modulation process consumes very low power. Data transfer from the transceiver is performed by pulse modulating the transmitted signal.

The concept features low complexity, small size and low power consumption in the vehicle side of the link. Frequencies used today are 2.45, 5.8 and 9.9 GHz. The communication range is approximately 5-10 m and data rates in the order of a few 100 kbits/s.



Example of Automatic Debiting System based on microwaves.

SHORT RANGE LINKS FOR FUTURE APPLICATIONS

In the last years there has been an increasing interest from authorities and companies within the traffic sector to improve the efficiency and safety of the total road transport system. Such improvements will involve both the vehicles and the road components.

Illustrations of this trend are the European projects DRIVE (EG) and PROMETHEUS (Eureka) which are now in operation. These projects aim at developing technology for

- o Dynamic route guidance
- o Improved traffic safety
- o Improved traffic flow

New types of systems are needed for short range communication between the vehicle and the roadside as well as between vehicles. These communication systems will also be able to handle various road pricing concepts.

Vehicle-roadside links

The communication between the vehicle and the roadside is essential for applications like

- o Driver information systems
- o Navigation
- o Traffic control
- o Route guidance
- o Road pricing

Roadside beacons connected to higher level systems and onboard transceivers provide the physical link. Necessary communication range is in the order of 10-30 m with data rates below 1 Mbit/s.

The road side equipment can be mounted on canopies, traffic posts etc. the most suitable location for the on board equipment seems to be behind the windscreen. The price has to be very low for the on board equipment. Current estimates of tolerable market price is 50 - 80 $ for the communication equipment.

Vehicle-Vehicle links

Physical links between vehicles creates a powerful tool for increasing road safety. Both communication, identification and relative positioning are required.

Examples of applications now being explored are:

- o Intelligent cruise control
  Monitoring/controlling the relative speed and distance between two adjacent vehicles in the same lane.

- o Cooperative driving
  Intelligent manoeuvres and control of operations like lane changing, merging and overtaking on highways.

- o Emergency warning
  Alerting rescue services and warning other drivers in case of accidents.

SOME TECHNICAL PROBLEMS

Price

The requirements on low costs for the on board equipment puts a firm limit on the complexity. For vehicle-roadside links with communication range below 30 m reflecting transponders reduces the microwave circuitry to a minimum. Systems operating below 10 GHz seem to match market demands today, while systems operating at mm bands still seem to be too expensive for the current markets.

In order to obtain manufacturing costs for mm systems that can meet the requirements on the market MMIC techniques are necessary, at least for on board systems. Today European companies speak of a 5 $ per mm² for integrated circuits up to 30 GHz. At 60 GHz the forecasts are more vague.

Frequency allocation and band width requirements

The requirements on data rate for vehicle-roadside links is in the order of 1 Mbit/s. For vehicle-vehicle links some applications seem to demand data rates in order of 10 - 20 Mbit/s. One reason is the greater communication range (300 m) and thereby the number of involved vehicles which can be 30 - 100.

The congested spectrum below 20 GHz has led to an interest in mm frequencies. Particularly the stopband around 60 GHz is of interest. The high attenuation in this band allows frequent frequency reuse.

Reliability and real time performance

In applications where safety is involved, for instance autonomous cruise control and cooperative driving, the requirements on reliability must be set very high. Loss of function must have a very low probability. Erroneous function must be fully excluded. The following parameters have to be considered:

- o Physical integrity
  The requirements on robustness of the equipment is dependent on the mounting on the vehicle. Components located outside the car body must endure a very demanding environment regarding temperatures, humidity, dirt and vibrations. Inside mounting reduces the requirements considerably.

- o Environmental effects on transmission
  The environment affects the transmission properties. An extremely heavy rain (40 mm/hour) gives an attenuation of 7 db/km at 60 GHz. Layers of dirt, snow and water on the antenna apertures affects the transmission strongly. The attenuation is considerably worse in the mm band than at lower frequencies. Inside mounting might give some advantages compared to outside. The windscreen in itself does not affect the propagation significantly.

- o Signal propagation
  Multiple path propagation due to reflections may cause a rapidly changing signal strength. 20 - 30 dB signal drops are not unusual. Occasional break down of the channel seems inevitable.

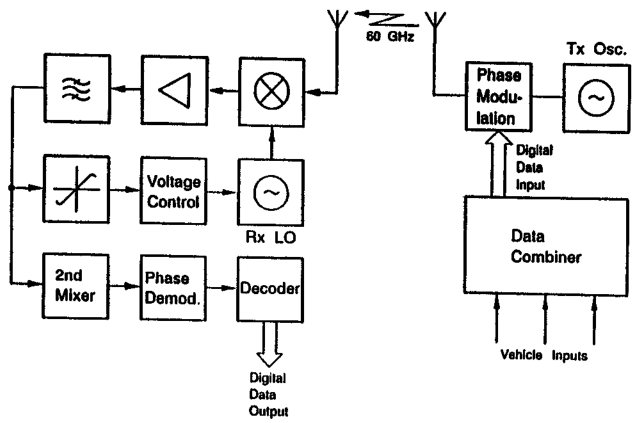
- o Channel access
  The unknown and rapidly changing number of vehicles inside a communication cell calls for new solutions in channel access strategy and coding techniques in order to assure good real time performance.

Spatial resolution

If a message is received from another vehicle it is essential for the interpretation to know the physical location of the transmitting vehicle. Therefore in vehicle-vehicle communication relative positioning and identification must be integrated. The required positioning accuracy is a few meters if the relative distance is short. The lateral resolution must be good enough for identifying in what lane neighboring vehicles are positioned.

SOME REALIZATIONS

One example of a 60 GHz communication test system for vehicle applications under development by Standard Elektrik Lorenz AG and Marconi Command and Control Systems Ltd. is shown in the picture below.



Block diagram of short range 60 GHz system

The system is designed for a communication range of 300 m with a data speed of 500 kbits/s. The system works with time slots with a length of 0.5 ms and a message length of 274 bits. Communication between about 30 vehicles can be obtained with an update rate of 10 times per second using TDMA access schemes.

The link uses DPSK modulation. In order to obtain frequency stability AFC is used in the receiver. The transmitter power is 20 mW.

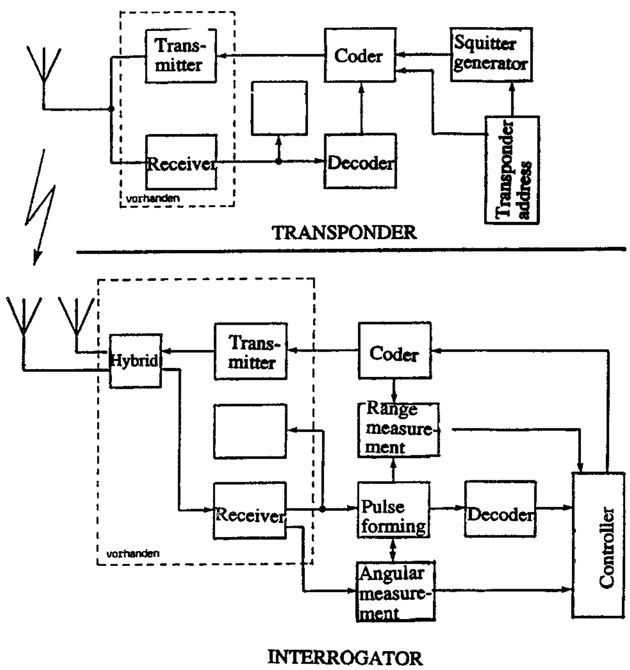
The system is intended for experiments with vehicle-vehicle and vehicle-road communication. The current version has no provisions for positioning finding.

5.6 GHz transponder system

The institute of transportation at Braunschweig TU Braunschweig is studying a discretely addressed transponder system which will provide both communication and position finding.

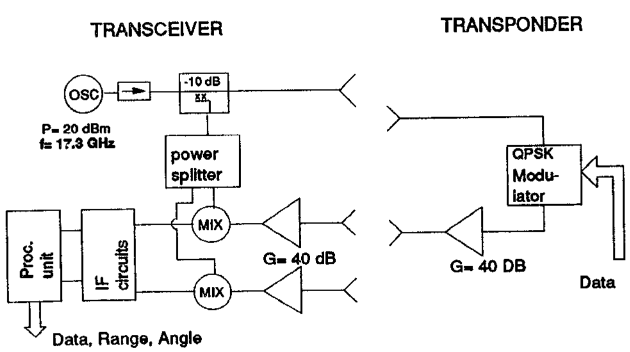
The system operates at 5.8 GHz. Every vehicle in the system carries a transponder and an interrogator. Both units are complete transceivers. The interrogator measures the time between transmission of interrogation and reception of reply for range determination. In a discretely addressed system every vehicle gets a unique address and a transponder will only reply to interrogations which contains this address. For acquisition every transponder transmits randomly so called squitters, which distributes its address to all interrogators.

The transponder antenna is omni directional whereas the interrogator antenna locks mainly forward with a range of 600 m ahead with smaller sidelobes to the side and aft. A block diagram of the system is shown below.



COMPOSE

COMPOSE (COMmunication and POSitioning Equipment) leans on two system components, the transceiver and the semi passive transponder.



Block diagram of COMPOSE system

When data is transferred from a transponder to the transceiver, the latter functions as an interrogator. Data transfer from the transponder is made by transmitting a CW signal towards the transponder. The reflected signal from the transponder is modulated by an electronically controlled reflection coefficient. In that fashion a sequence of data is formed which is received in the transceiver. The data sequence can either be an identification code or a stream of data. The frequency selectivity lies in the transceiver unit whereas the transponder has practically no frequency selectivity. For transmission of data in the other direction the transponder can be equipped with a detector. The complexity of the transponder is low compared to that of the transceiver.

Ranging is accomplished by phase difference measurements at a few different frequencies. Measurement of lateral angle is accomplished by using two or more receiver antennas at different lateral locations.

All together we have the following functions:

- Reading data from semi passive transponders
- Transmitting data to semi passive transponders
- Position determination of transponders (Range and Angle)

A test system now being developed at the Institute of Microelectronics operates in the 17 GHz band. The communication range is 200 m with a data rate of 256 kbits/s and a measurement accuracy of 1 - 3 m. The acquisition time is 2 ms. FSK modulation is used and the access techniques is based on slotted aloha.

The system is intended for experiments and demonstrations with vehicle-roadside communication, intelligent cruise control and collision avoidance.

CONCLUSIONS

A first generation of short range microwave links for traffic and transport applications is already on the market and is used primarily for automatic debiting systems.

Within the European research programs Drive and Prometheus more advanced systems are being studied addressing dynamic route guidance, traffic safety and traffic flow problems. For cost reasons an integrated system for all functions is desired. Current implementations cover the frequency range from 2.4 GHz to 60 GHz and use either semipassive transponders or fully active two-way transceivers.

As roadside components are important parts of the system a European standard is considered necessary. An important objective of current developments is therefore to gain sufficient information for decision on standardized frequencies and communication protocols.