A Wireless Data Link for Mobile Applications

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***Abstract*—A short overview is given on wireless high speed data links for local-area-ad-hoc-networks in mobile applications and a multifunctional CDMA-Direct-Sequence Spread-Spectrum communicating platform is investigated which may be used for inter vehicle communication as well as for object detection and ranging in the environment of cars.**

***Index Terms*—Communication, direct sequence spread spectrum (DSSS), mobile, wireless.**

I. Introduction

WIRELESS data links are of increasing importance in mobile applications. Cars have to be linked with each other in an inter-vehicle-communication (IVC) and in road-to-vehicle services [1] e.g., for traffic guidance systems, traffic adaptive cruise control, cooperative maneuvering and hazard warning systems. The data links offer to be used dually in a multifunctional concept where the transceivers are base for the IVC as well as for a near range sensor in order to detect objects in the near environment of the cars. For mobile ad-hoc networks there are special demands to be fulfilled like high dynamics, channel separation, high immunity against external interference and the prevention of multipath fading. Code Division Multiple Access-wireless systems have proven to fulfill these demands well, if there is enough bandwidth available, e.g., [2], [3]. These systems have already been proposed for inter-vehicle communication (IVC) and ranging [4]. The direct-sequence spread-spectrum (DSSS) of the CDMA-systems with high chiprate enables channel separation, a high immunity against external interference and the transmission with low emission level. The spreading codes with high chiprate are used for a pseudo-noise radar system in order to detect objects in the environment of the car. The combination of object detection and communication between cars offers the possibility of a high quality driving assistance system where safety, warning, traffic prediction, and traffic guidance functions are integrated. A problem of mobile wireless systems are fading effects because of multipath propagation [5]. Performing channel estimation for preventing such problems would lead to a high effort in the physical layer but also in the protocol layer. In this paper we propose a multifunctional CDMA-DSSS communicating platform which may be used for different kinds of inter-vehicle communication as well as object detection in the environment of cars. In this platform a flexible CDMA system is used for the combination of inter-vehicle communication in the range of at least 0 m to 50 m and the tracking of objects in the near range of at least 0 m to 10 m. Fading effects can be suppressed via diversity of multiple communicating sensor elements.

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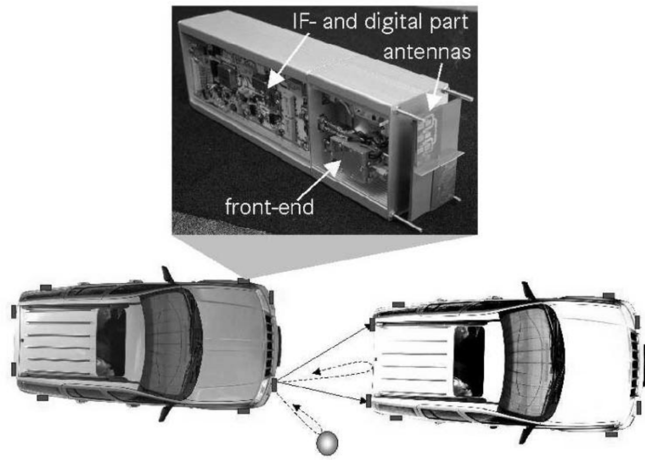

Fig. 1. DSSS-transceiver integrated into the cars surface; arrows: transmission paths for one PN-code (one channel); solid lines: diversity data transmission to transceivers of other car; dashed lines: distance detection at the same time.

II. Communication and Ranging Platform

In order to detect the position of objects and to track its trace an array of small transceivers is positioned around the cars surface [7], [8] which are networked with each other (Fig. 1). Each transceiver emits a pseudo-noise coded signal of up to 450 Mchip/s at a carrier frequency of 24.1 GHz which is back-scattered by the radar targets in the environment of the vehicle. In the receiver the time delay of the backscattered signal and hence the distance of the radar target is measured via the correlation function between the received signal and the emitted PN-code [7].

We consider two approaches for implementing the IVC in combination with the ranging system. The first approach is the application of different DSSS code systems for IVC and ranging. Hence these code systems can be tailored to the different needs of communication and radar function. An other advantage for early applications is that commercially available components from existing WLANs can be integrated into the system using also its protocol layer. To be specific, we considered a WLAN according to IEEE 802.11b. This WLAN is designed for a frequency band around 2.4 GHz. We have chosen IEEE 802.11b because it is a DS-CDMA system and not sensitive to Doppler spread of less than 10 kHz which may occur in a traffic environment. This is a distinct difference compared with a multi-carrier CDMA system [e.g., IEEE 802.11a (OFDM)] which is vulnerable to Doppler spread. The DSSS code is the 11-Chip Barker Code. For our purpose this band has to be upconverted to 24.1 GHz with mixers. In

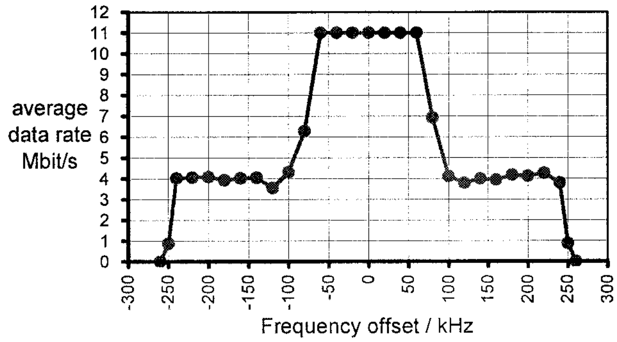

Fig. 2. Data rate in dependence of the frequency offset between the RF sources in two modems.

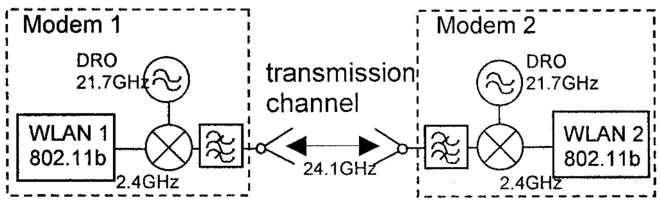

Fig. 3. 24.1 GHz Modems with DROs as LOs.

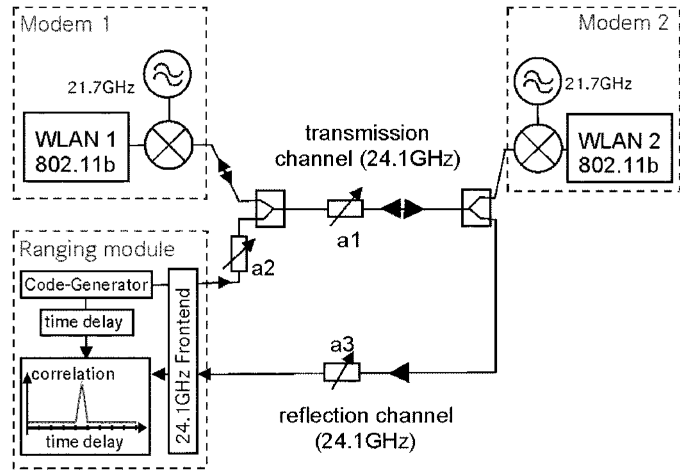

Fig. 4. Arrangement for the measurement of the radar SNR and the communication quality for the combination of radar and communication in one transmission channel.

order to avoid additional efforts for carrier synchronization it would be advantageous to use the phase locked loops which are implemented in the commercially available WLAN modems. We made experiments with a set-up consisting of two WLAN modems (artem PCMCIA cards), two mixers and two synthesizers which served as local oscillators (LO). We introduced a frequency offset between the LOs and observed the average data rate between the modems versus this offset. The result is displayed in Fig. 2.

The modems are using different modulation schemes, depending on the channel conditions (attenuation and dispersion). From Fig. 2 one can recognize that the maximum data rate of 11 Mbit/s is achieved as long as the offset is lower than $+-60$ kHz. This data rate corresponds to Complementary Code Keying modulation (CCK). When the offset is increased other modulation schemes [DQPSK (2 Mbit/s), DBPSK (1 Mbit/s)] are applied with a corresponding reduction of data rate. Above around $+-250$ kHz no communication is possible. The permissible offset is sufficient to use relative cheap quartz stabilised dielectric resonator oscillators (DRO) as LOs in the final application.

A transmission experiment with the application of such DROs is sketched in Fig. 3. A maximum permissible channel attenuation of about 50 dB has been measured with a data rate of 11 Mbit/s. An important question is the reduction of SNR due to the cross-correlation between the Barker code and the pseudo noise code of the radar. With the arrangement according to Fig. 4 this question has been checked. The signals from modem 1 and the radar were superposed with a 3 dB Wilkinson divider. The modems correspond to Fig. 3. A variable attenuator allowed a variable power ratio between these signals. The attenuators a1 and a3 simulated a variable channel attenuation respective radar reflection. The measurements yielded the following results: 1) Communication is possible as long as the radar transmitting power does not exceed the communication transmitting power by more than 9 dB. 2) The radar SNR is reduced under this condition by about 2.3 dB.

In a second investigation, we consider a concept for long terms which represents the physical layer of a CDMA DSSS-based communication platform using the long PN-codes of the ranging sensor also as spreading codes for data transmission. This enables the dual use of the main part of the hardware (including also the baseband signal processing) for the ranging and IVC functions. Based on the hardware for the ranging application only a small hardware extension is required in order to realize the additional function of IVC. In Fig. 5 the concept of the transceiver is shown combining ranging and communication with each other. In the transceiver module data with 0.45 Mbit/s are emitted at a carrier frequency of 24.1 GHz after spreading it with a high speed PseudoNoise-(PN)-Code 1 with the length of 1023Chip and a chiprate of 450 Mchip/s. In the receiver the same signal 1 is received after being back scattered by the radar target. An other data signal 2 with the spreading code 2 is received, being transmitted via a transceiver of an other car. From the time delay of the signal 1 the distance of the reflecting object can be derived. For the IVC the time delay of signal 2 is required in order to synchronize the receiver with the transmitter of the other car. In order to obtain the time delay of signal 1 for the ranging application the received signal is correlated with signal 1 after it has been delayed by a variable time delay (Fig. 5). The correlation yields a maximum value when the variable time delay hits the value of the time delay corresponding to the length of the signal path to the radar target and back. For the IVC the received signal is correlated in the same way with the code 2. The sign of the correlation maximum shows the logical value of the transmitted data. At a transmitted data rate of 0.45 Mbit/s an additional gain of 30 dB is possible increasing the SNR. But higher data rates are possible too, taking into account a decrease in dynamics for the radar function and the correlation gain. After networking the transceivers in the base band they can work together as a diversity system where fading effects are suppressed. In the case of multipath transmission with differences between time delays in the paths of more than one PN-code chiplength it is

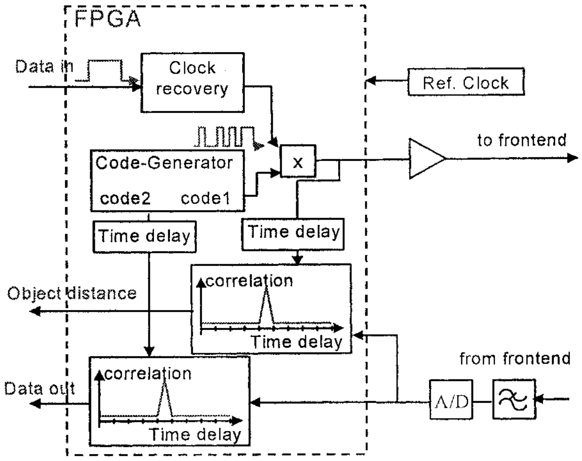

Fig. 5. PN-radar and data transmission unit.

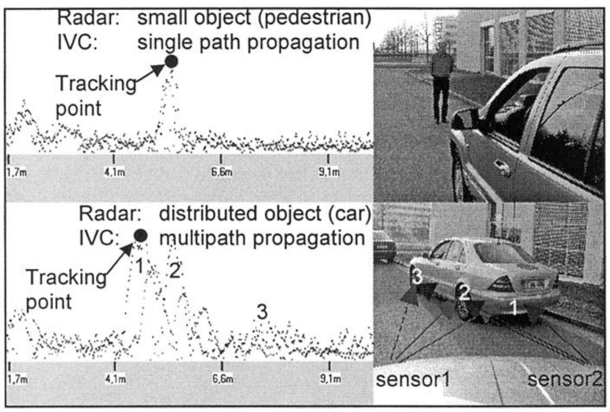

Fig. 6. Correlation function at different scenarios e.g., radar: pedestrian and car; In IVC similar functions occur at single- and multipath propagation.

also possible to separate the signals of the different paths in the correlation function. Each car emits signals with its own pseudo-noise codes: This leads to a high standard channel separation for IVC and the ranging application as well.

In the actual demonstrator realization two transceiver modules are integrated in the front bumper and two others in the side of a car, networked with each other in the base band. The distance and the direction of objects in the near range of the car are detected in a range of 0 m to more than 10 m with an update rate of 19 ms. Every sensor module is capable of monitoring several objects and for every object supplies signals indicating distance, direction and the speeds of objects.

The pseudo-noise code chip length of 2.2 ns yields an object resolution of 33 cm and a distance accuracy of only few centimeters. In Fig. 6, the correlation function over the object distance is shown for different scenarios. The capability of the near range sensor to monitor several objects has been tested for cars and pedestrians. The application of a sensor for the detection of objects in the complete near range around the car requires a special signal processing [8] which can be used for the IVC as well. The signal processing yields the time of arrival of the received signals which is used for distance measurement in the radar application and for synchronization between transmitter and receiver in the IVC application. In a first level of the signal processing the signals of each transceiver module are detecting the distance of the objects to the single transceiver modules and compensating noise and spurious external signals using special filtering algorithms. In a second level the data from the transceiver modules are processed together in a central signal processing unit, where the positions of the multiple objects around the car are calculated via triangulation. This unit also can serve as a diversity unit for the IVC in order to decide at which transceiver module the best dynamics are found. In a third level the movements of the objects and other transmitting cars are calculated taking into account also the velocity measured by the sensor. An object tracking function yields a faster update rate of the ranging sensor as well as it can be used for the steady synchronization of the receiving code and the transmitted code for the IVC.

III. Conclusions

A CDMA-DS/SS ad-hoc-network is investigated in which the functions of inter-vehicle-communication and object detection in the environment of the car can be combined, preventing common problems like fading and channel separation efficiently. The combined application of ranging and data transmission has been tested successfully for the IEEE 802.11b standard.

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