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An approach to converge communication and RADAR technologies for intelligent transportation system

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Abstract
The Intelligent Transport System (ITS) is an important and critical embedded system which should be carefully designed to fulfill the goals for safety and non-safety applications. ITS has been the umbrella under which significant efforts have been conducted in research, development, testing, deployment and integration of advanced technologies to improve the measures of effectiveness of national highway network. Efforts are being imparted towards a combined system of both communication and remote sensing technology. In the paper, the combined system construction principle of RADAR-location and information transmitting is considered. We modeled a communication and RADAR combined system in MATLAB considering WCDMA simulation model as reference. We considered moving target for simulation and it is detected at the RADAR receiver while the received information signal is processed through RAKE receiver to achieve low BER value. Thus the combined system is running successfully and satisfying both the requirements. This design can be implemented on reserved channel of Dedicated Short Range Communication (DSRC) for Intelligent Transport System (ITS) application.

Keywords: Intelligent Transport Systems (ITS); RADAR; WCDMA.

Introduction

In United States, there were 6279000 motor vehicle accidents that accounted for 41611 deaths in 1991. More dollars than any other cause of illness or injury are consumed for providing the health care regarding the treatment of crash victims. US department of Transportation has declared that the reduction of vehicular fatalities is its top priority. This is true for all other countries as well. Also demand for voice, data and multimedia services while moving in car increase the importance of Broadband wireless systems (Huang, 2006).

The Intelligent Transport System (ITS) adds information and communications technology to transport infrastructure and vehicles to improve safety and reduce vehicle wear, transportation times and fuel consumption etc. To provide potential benefits of ITS applications in a national highway network, a broad range of research and development efforts are being carried over under the umbrella of ITS Technology.

The first ITS research was developed by Japan in CACS (the comprehensive automobile traffic control system) in the year 1960s and 1970. Then it was stretched in US & Germany respectively. In Japan, work on the road/automobile communication system (RACS) project, which formed the basis for our current car navigation system began in 1984. ITS is expected to become very big business in near future. Industry, like skysoft has become the major European player on command and control systems for the road sector, both for highways and cities. A wide variety of Japanese and international concerns are already involved in planning and development of ITS (Kahaner, 1996).

Major technologies in ITS

ITS involves a broad range of wireless and wire-line communications-based information, control and electronics technologies. Short-range communications (less than 500 yards) can be accomplished using IEEE 802.11 protocols, specifically WAVE or the dedicated short range communications (DSRC) standard being promoted by the intelligent transportation society of America and the United States department of transportation. The US FCC has allocated 75 MHz of spectrum in the 5.9 GHz band (5.8 GHz for Europe and Japan) for DSRC to enhance the safety and productivity of the nation's transportation system.

Technological advances in telecommunications and information technology coupled with state-of-the-art microchip, RFID and inexpensive intelligent beacon sensing technologies have enhanced the technical capabilities that will facilitate safety benefits for motorist globally.

RADAR technology has been investigated for use on automobiles since the 1970s and has been employed for various functions on automobiles since the early 1980s (Belohoubek, 1987; Brus, 1987). Initial usage of microwave RADAR was for collision warning applications on commercial vehicles such as ambulances, buses and trucks. Prometheus, the ambitious European project that started in 1986, aimed to improve vehicle safety, efficiency and economy and was one of the main driving factors in the development of various types of sensors for automobiles, including millimeter wave RADAR. The advantage that RADAR sensors have over other types of sensors such as optical or infrared sensors, is that they perform equally well during the day, the night and in most

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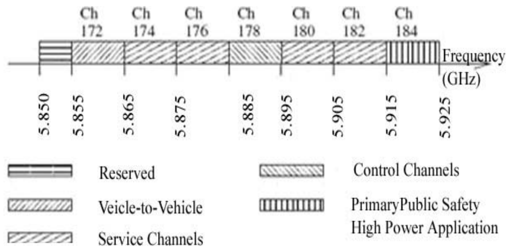
weather conditions. RADAR can also be used for target identification and for detecting road conditions by making use of scattering signature information. The problems of clutter, multipath and interference are more severe (Kandar & Bera, 2005). Proper technology in RADAR operation is to be implemented to mitigate those problems.

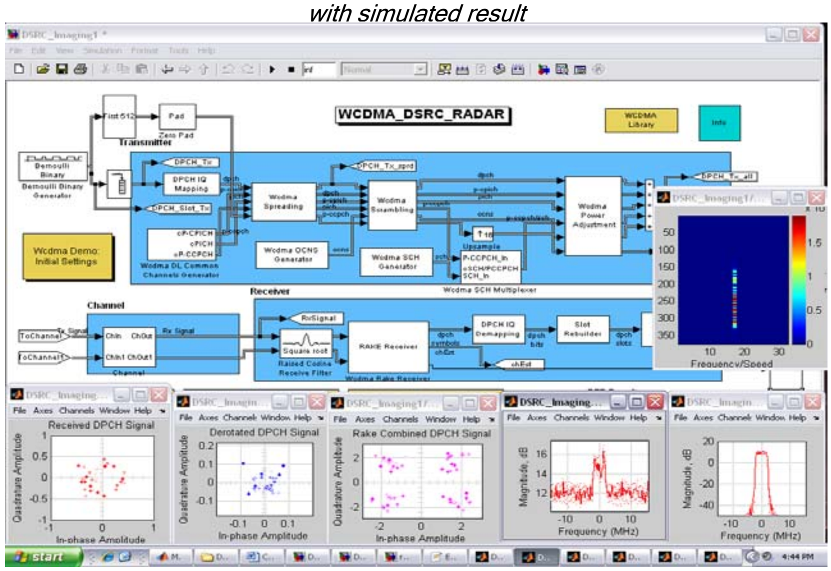
Fig. 1. DSRC channel scheme assigned in the United States



Spread Spectrum (SS) RADAR

The SS technology is well known for its anti- jamming and security features (Scholrz *et al.,* 1977; Dixon *et al.,* 1984; Cooper *et al.*, 1986; Torrieri *et al.,* 1992; Richard *et al.*, 1993; Glisic *et al.*, 1995; Viterbi *et al.,* 1995) in communication system and was initially developed for military and intelligence requirements (Hanzo *et al.,* 2003). The same technology can be utilized for better RADAR operation. Spread Spectrum systems employ waveform similar to those of pulse compression RADAR.

Fig.2. Block diagram of communication and radar combined system with simulated result

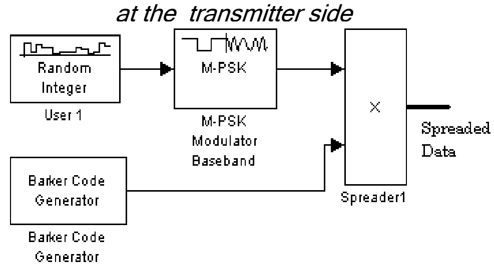


Advantages over conventional RADAR

The design & development of RCS Instrumentation RADAR at the low frequency band should be aimed for the additional benefits such as: local suppression of Interference due to coded RADAR waveform & correlation of the received code, high level of rejection of multipath and higher reliability / efficiency & low power consumption due to coding of the baseband pulses.

Accordingly, the waveform of choice will be Phase Coded Pulse Compression using digital techniques instead of linear frequency modulation (LFM) based analog techniques. Sometimes pulse compression RADARs have been called spread spectrum RADARs (Knott, 2004; Skolnik, 2007). Therefore, DSSS RADAR will be aimed for the development.

Fig. 3. Base band spreaded data generation at the transmitter side



Dedicated short-range communication

Short-range communication can be accomplished using IEEE 802.11 protocols, specifically WAVE or the DSRC standard being promoted by the intelligent transportation society of America and the United States department of transportation. DSRC, a sub-set of the RFID-technology offers communication between the vehicle and roadside equipment. This technology for ITS applications is working in the 5.9 GHz band (U.S.) or 5.8 GHz band (Japan, Europe). Frequency allocation for DSRC channels are shown in Table 1. Dedicated short range communication (DSRC) (Armstrong, 2008), standard being promoted by the intelligent transportation society of America and the United States department of transportation for short range communication in ITS. DSRC, which is a candidate for use in a VANET offers the potential to effectively support in ITS. A number of wireless solutions were evaluated for use as the primary communication medium for DSRC (VSCC, 2005) which enables a new class of communication applications that will increase the overall safety and efficiency of the transportation system.

DSRC as communication system for ITS

First generation DSRC was used for toll collection system operates at 915 MHz and has a transmission rate of 0.5 Mb/s. The federal communication commission (FCC, 2002) allocated the 75 MHz of bandwidth in the 5.9 GHz band for the second generation of DSRC. Since the allocation of the bandwidth, standardization bodies have been working on the implementation details of 5.9 GHz DSRC. To reduce the traffic hazards, the North American DSRC standards program aims at creating an interoperable standard for use in the US, Canada and Mexico. Furthermore, 5.9 GHz DSRC must have a low cost and be very

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scalable. In addition, the 5.9 GHz DSRC should require no usage fee from the users to access the network.

Now same DSRC channel can be utilized for RADAR operation. The 5.9 GHz DSRC spectrum is composed of 6 service channels and 1 control channel each having bandwidth of 10 MHz as shown in Fig.1. The first (remaining) channel of DSRC (having 5 MHz bandwidth) is reserved. This reserved channel (5.850-5.855 GHz) can be used for remote sensing which involves spread spectrum based digital RADAR technology.

RADAR as remote sensing device

There are various kinds of sensors available for ITS applications as remote sensing devices. The remote sensing devices based on using sensors are pneumatic road tubes, inductive loops, magnetic sensors, piezoelectric sensors, video cameras, infrared lasers sensors, microwave (MW) RADARs and ultrasonic sensors (Mimbela & Klein, 2000; Hsieh *et al.,* 2006). Sensor will provide a specific mechanism of detecting vehicles and has its own advantages and disadvantages. Since user needs and classification conditions can differ, no sensors and corresponding techniques have proven to be the best for all possible applications (Mimbela & Klein, 2000) (FHWA-PL-01-021, 2001).

RADAR technology has been investigated for use on automobiles since the 1970s and has been employed for various functions on automobiles since the early 1980s (Belohoubek, 1987; Brus, 1987; Wegner, 1998; Gandhi & Trivedi, 2006). RADAR is having the advantage of high detection range, high range resolution and lower algorithmic complexity with moderate hardware cost. The advantage that RADAR sensors perform equally well during the day, the night and in most weather conditions (Dixit & Rafaelli, 1997; Gandhi & Trivedi, 2006). Considering the physical size of the RADAR sensors most current millimeter-wave RADAR systems operate in the 76-77 GHz frequency range (Dixit & Rafaelli, 1997; Wegner, 1998).

Table 1. DSRC channel no. with operating frequency

Channel no.	*Frequency (GHz)*
172	5.855 - 5.865
174	5.865 - 5.875
175	5.865 - 5.885
176	5.875 - 5.885
178	5.885 - 5.895
180	5.895 - 5.905
181	5.895 - 5.915
182	5.905 - 5.915
184	5.915 - 5.925

Though in various traffic management applications, roadside mounted and forward-looking frequency-modulated continuous wave (FMCW) and noise-correlation RADAR units combined with continuous-wave (CW) → doppler sensors are commonly used (Roe & Hobson, 1992; Walton et al., 1997). RADAR operation in a moving vehicle is very difficult because of ground clutter problem. Instead of using analog operation, digital RADAR operation will help in ITS.

Fig. 4. Target model methodology

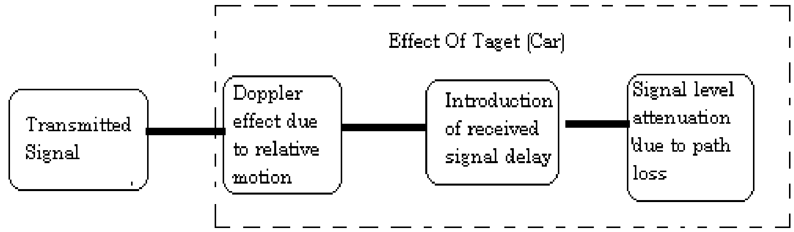


Fig. 5. Target model for RADAR system

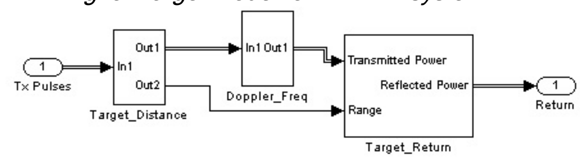
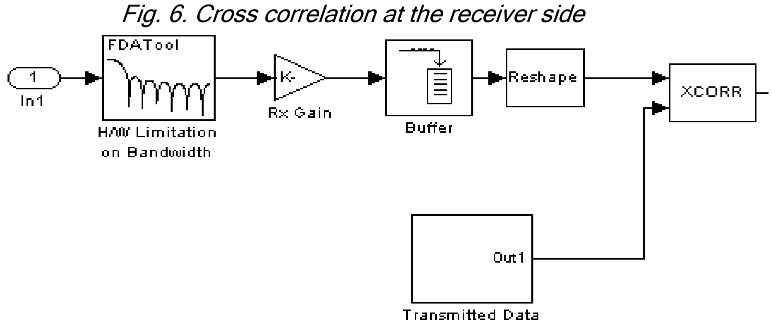


Fig. 6. Cross correlation at the receiver side



Combined RADAR System

In the combined system of RADAR tracking detection of the targets and information transmitting on the two separate reserved DSRC channel. We modeled a communication and RADAR combined system in MATLAB considering WCDMA simulation model as reference.

The procedure to construct a combined channel for a RADAR target detection and digital communication system consists in the following.

- Construction of the RADAR and communication combined system. In this paper we use WCDMA physical layer simulation as reference. As in DSRC, we use 2 separate channels, 1 for RADAR purpose and other for communication.
- For both the communication and RADAR purpose we have used spread spectrum technique. For both the cases we have use 2 stage modulation techniques.
  (a) QPSK modulation.
  (b) Spread spectrum modulation using high data rate chip signal.
- Complex signal processing for noise immunity of the combined system.
- The estimation techniques of the signal power parameters for joint system of a RADAR- location and communication. In this paper to equalize the received

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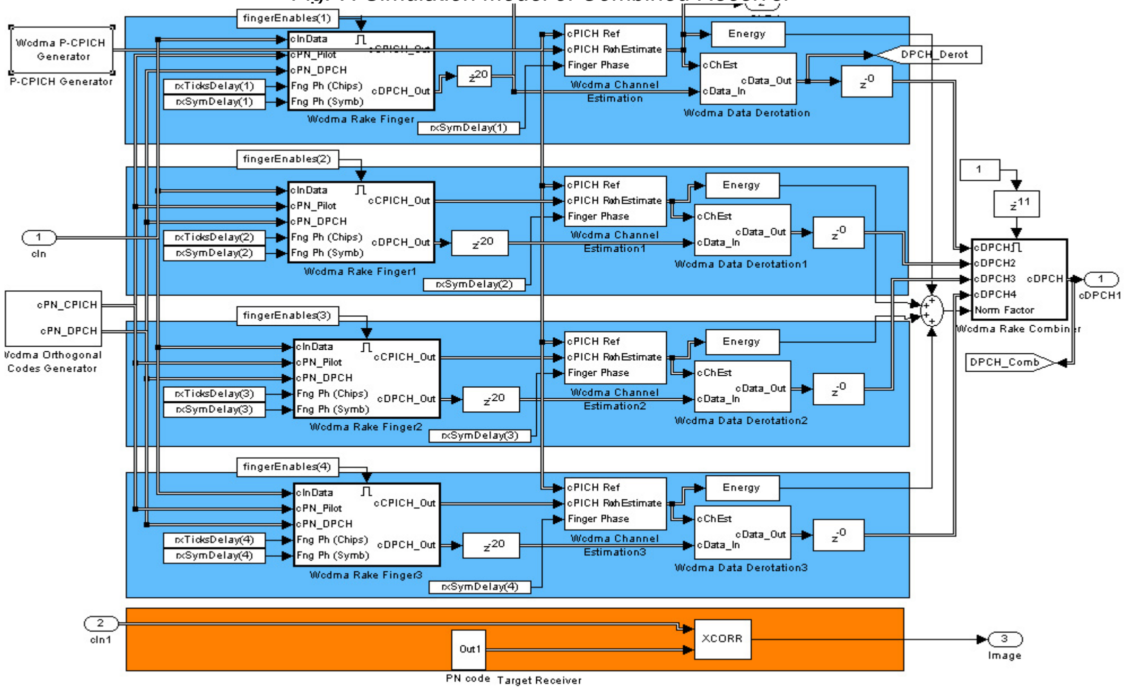
Fig. 7. Simulation Model of Combined Receiver



distorted data and to enhance the communication system performance in term of low BER value we have used RAKE processing. Also in Spread spectrum RADAR target ranging is nothing but a correlation process. In our design we have correlated the received signal with the reference code (same as in transmitter section for spreading).

The communication system model part of the frequency division duplex (FDD) downlink physical layer of the third generation wireless communication system following the specifications of the WCDMA system are developed by the Third Generation Partnership Project (3GPP). The WCDMA air interface spreads encoded user data at a relatively low rate over a much wider bandwidth (5 MHz) using a sequence of pseudorandom units called chips at a much higher rate (3.84 Mcps). By assigning a unique code to each user, the receiver which has knowledge of the code of the intended user can successfully separate the desired signal from the received waveform. BER (Bit error rate) Calculation shows the results of the BER computation block associated with each transport channel separately.

Simultaneously the system is able to detect the target in a multipath channel. The simulation model and results of the combined system is shown in Fig. 2. The constellation diagram of the transmit, received (before and after RAKE combining) signal, the spectrum of transmitted & received signal and the detected target are also shown in the same Fig. 2.

Transmitter

In transmitter section of SS RADAR operation as shown in Fig. 3. Modulated waveform is modulated (spread) again over an expanded bandwidth wideband signal that does not significantly interfere with other signals. In our designed we used 13 bit Barker code as PN code and after spreading we have up converted it and transmitted it to the channel

Channel and target model:

In channel modeling we considered multipath channel. We introduce the relative motion between the cars by incorporating Doppler Effect to the transmitted signal by taking into account of motion of the car. We also successfully developed a target model. The transmitted signal gets reflected form the target and we measure the time in order to find its relative position. The schematic diagram of our designed target model is shown in Fig. 4. The block diagram of the target model and the simulation model is shown in Fig.4 and Fig.5.

Receiver

In receive section of SS RADAR operation, correlation plays an important role. Same barker code has been used as PN code for correlation. The basic block diagram of SS RADAR receiver is shown in Fig. 6.

When the size of the target is fixed the normalized cross-correlation method can be directly applied for Target Tracking (Behrad *et al.,* 2001). We use XCORR Simulink block in order to cross correlate the received signal with the transmitted signal. And find some interesting result showing the car movement.

Fig. 7 shows the combined RAKE receiver simulation model which includes RAKE processor (four blue blocks) for communication device as well as for RADAR device (orange block).

Conclusion

The demand of ITS encourage us to work for converging of communication and RADAR technology. DSRC is well established in communication system. We successfully simulated RADAR model combined with communication model. The MATLAB simulation model is able to calculate BER (Bit error rate), PER (Packet error rate) as well detect the target. The system is able to measure the target distance. It also can separate different targets placed 30 m apart.

But we considered all aspects of RADAR operation in the base band level. As SS technology is implemented in DSRC, no extra channel is required for RADAR operation. Also unwanted scatterers are eliminated to a great extent. As the RADAR can be implemented in car its physical size is very important parameter for its commercial use. So the radio part of the RADAR should operate in higher frequencies like 90 GHz or more. Other techniques like MTI can detect moving targets from ground clutter, even in the bad weather by virtue of the doppler radar return of the moving targets (Repesh, 2002; Dunn *et al.,* 2004). RADAR can extract the doppler frequency shift of the echo produced by a moving target by noting how much the frequency of the received signal differs from the frequency of the signal that was transmitted.

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