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Vladimir KRYLOV[1]

ULTRA WIDE BAND RADIO TECHNOLOGY IN TRANSPORT SYSTEMS TELEMATIC

New UWB technologies according to FCC US Report 02-48 for transport system telematic application are presented. The possibility of using ultra wide band radio technology for combined communication and collision prevention (C&CP) system building is discussed. Functional diagram of integrated C&CP system is shown.

TECHNOLOGIA SZEROKOPASMOWEGO SYGNAŁU RADIOWEGO W TELEMATYCZNYCH SYSTEMACH TRANSPORTOWYCH

Jednym z ważnych problemów w czasie tworzenia inteligentnych systemów transportowych (ITS) jest bezpieczeństwo. Zapobieganie kolizji i system krótkiego zasięgu nawigacji wymagają dokładności lokalizacji jednostek transportowych na bardzo wysokim poziomie. Ten referat rozważa możliwość zbudowania zintegrowanego systemu nawigacji, wymiany informacji i lokalizacji opartej na użytkowej technologii sygnałów szerokopasmowych. Każdy pojazd musi być wyposażony w nadajnik – odbiornik szerokopasmowy i układ pomiarowy opóźnień czasowych.

1. INTRODUCTION

One of the important problems while building intelligent transport systems is safety provision. Collision prevention and short-range navigation systems require very high precision of transport units location and high precision of conjugation of navigation and location fields, which are the main sources of information on Intelligent Transport System (ITS) and objects surrounding it. This work considers the possibility of building an integrated system of mutual navigation, information exchange and location based on UWB signals technology usage. Below we examine the task allotment and basic definitions used in the work, as the subject matter of this work has no stable terminology and notional mechanism.

1.1. TASK ALLOTMENT

Let us consider the following task allotment. An ITS consists of multiple mobile transport units, moving on the surface or in a three-dimensional space. Transport units have different overall dimensions and different travel speed. Each transport unit may be equipped with its own navigation subsystem, *e.g.*, GPS, inertial, LORAN b, etc., status and orientation

[1] Nizhny Novgorod Technical University, Minina, Nizhny Novgorod, Russia, krylov@unc.sci-nnov.ru

sensors and other means. The information, coming from all such means may downloaded in a common container, its content being updated in real time. Hereinafter we will call this information container along with its content – transport unit signature. Let us also suppose that on the ITS deployment area there are fixed and mobile objects, that are not part of the system. Hereinafter we will call the set of such objects ITS environment.

Global task of the system is to provide the movement of each transport unit over allowed trajectory at preset time schedule, with preset safety, the level of which is defined by the probability of collisions of transport units with each other and with the environment.

Let us examine the task of providing the prevention of collisions of transport units between each other and with the environment by placing additional equipment on board of each transport unit. Natural requirement, when designing such an equipment, will be minimization of its mass-dimensional indices and cost.

Typical approach to creating collision prevention systems consists of either deployment of external system of tracking all transport units and the environment with information transmit to the transport units, or equipping each transport unit with detection means of environment objects and other transport units in near zone. Taking the decision on danger and working out control reactions may also be performed by ITS central resource or autonomous equipment of each transport unit. Thus, two subsystems may be distinguished in the collision prevention system: determining the distance to all ITS objects and the environment, and information transmit. The basic problem when designing such subsystems is the need of providing high precision of distances determination and sufficient carrying capacity at low costs for production and deployment.

We believe that a compromise solution may be the application of UWB signals technology, that have been under development long ago and only of late it acquired the status of commercial technology.

1.2. UWB TECHNOLOGY

In February 2002 USA FCC by its decision changed Part 15 of the commission's Rules regarding UWB transmit systems and permitted commercial application of communications systems and radio location, using radio signals with the spectrum the width of which exceeds 1.5 GHz.

This technology is based on the use of pulses of rather short duration of nanoseconds portions, these pulses being used as carrier signals. Spatial duration of such pulses is rather small and constitutes in the air one and less of ten of centimeters. Information transmit rate in a channel, made up by such signals may be hundreds of megabits and gigabits per second. The basis of the equipment is made up by rather cheap semiconductor devices of short video pulses generation and their time modulation, and also by coherent accumulation circuits. Currently, many leading manufacturers of computer systems turned their attention to the availability of such a technology for building wireless networks of short range (ten meters). Intel had announced a number of developments and established the center of investigations and developments in this area. A number of companies already propose chip sets for realization of UWB radio interface. Thus, it is possible to believe that in the nearest time at the market there will appear the element base for UWB systems building, the investigations in this area will get a new incentive and the consumers will be able to consider UWB technology as a real alternative to other known methods of building wireless systems of communications and radio location.

2. UWB COMMUNICATION AND COLLISION PREVENTION SUBSYSTEM

This section presents the author's approach to building C&CP subsystem that uses UWB technology. This approach is based on the results of investigations conducted by the laboratory of Nizhny Novgorod Technical University under the guidance of the author during the period of 1989-1994. The basic idea is protected by Russian Federation patent №1779150 of April 6,1993.

2.1. THE METHOD OF DETERMINING THE DISTANCE BETWEEN TWO OBJECTS

This method provides the measurement of the distance between two objects, which have the equipment for information transmit and receive by means of short pulses with fixation of moments of transmit and receive of each information packet. The core of the method is in the following. Radio signal pulses are emitted periodically at the first and the second objects at time moments t_{11} and t_{22}. At time moments t_{21} and t_{12}, respectively the signals emitted by other object are received at the first and the second objects. Time intervals $\tau_{12} = t_{12} - t_{11}$ and $\tau_{21} = t_{21} - t_{22}$ are measured at each object. The information packet, containing these values, is transmitted from one object to the other. The distance between the objects is determined by calculation by a simple formula

$$R = c/2(\tau_{12} + \tau_{21})$$

where c – speed of light. The following figure represents time diagrams explaining the described method.

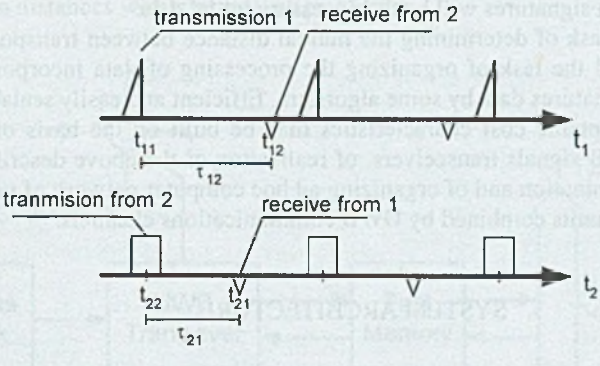

Fig.1. Time diagrams for thje first and the second objects

A remarkable property of the proposed method is high precision of distance determination, independent on objects effective reflective surface, and defined only by the accuracy of measuring the moments of signals arrival, and hence by the width of the spectrum of radiated signals and by the stability of emission periods.

2.2. THE BASIC IDEA OF BUILDING COLLISION PREVENTION SYSTEM

Let us consider ITS deployment space containing transport units and environment. At each moment of time the system status will be defined by the set of coordinates of each ITS object, the environment objects and the aggregate of signatures of each transport unit. The multitude of potential statuses may be divided into two non-crossing sub-multitudes – normal location and dangerous location.

In the statuses of normal location the system functioning does not require the interference to prevent a collision of one object with another, while dangerous location is characterized by the decrease of at least one mutual distance to such a value when objects collision may be forecasted taking into account the objects signatures, if special interference into the control of transport units movement is not performed.

Collision prevention system task is to evaluate the value of function of identity of ITS status to earlier defined sub-multitudes – normal and dangerous locations at each moment of the time. The algorithm of evaluation may be built on the basis of two-stage procedure. All mutual distances between transport units and the environment objects are analyzed at the first stage. Then, the pairs are selected for which the distances are in advance less than the preset threshold, and for them the objects signatures are analyzed. Based on this analysis it is possible to calculate the time prior to potential collision. Some non-linear transformation from the value of this time may be used as desirable function of identity to the sub-multitude of dangerous location. For example, threshold non-linear function with values of zero and one may refer the current status to a dangerous location, if the time to collision, calculated by the distance between two objects and dynamic characteristics known from the signatures, will be less than the threshold value. Collision prevention system may use other, more complex algorithms of evaluation of danger degree, but in any case the mutual distances and objects information containing in signatures will be the necessary initial data.

Thus, there is the task of determining the mutual distance between transport units and environment objects, and the task of organizing the processing of data incorporating these distances and objects signatures data by some algorithm. Efficient and easily scalable solution of these tasks with acceptable cost characteristics may be built on the basis of equipping transport units with UWB signals transceivers, of realization of the above described method of mutual distance determination and of organizing ad hoc computer network of processors of closely located transport units combined by UWB communications channels.

3. SYSTEM ARCHITECTURE

This section describes hypothetic collision prevention system, using UWB signals. This system architecture, the composition of functional modules is proposed and their required technical characteristics are evaluated.

3.1. FUNCTIONAL DIAGRAM

Figure 2 shows how local clusters of transport units are formed in spatial areas, where the objects closed in to the distance of providing stable communication and/or the environment objects happened to be in the zone of effective reflection of UWB signals. In every cluster, where there at least two transport units, ad-hoc computer network is formed that computes the mutual distances. The data on reflection of its own signal as in conventional radiolocation systems are used for the environment objects. This information is also used by the network or by a single processor (if there is only one transport unit in the cluster) to calculate the distance and to take a decision on the identity of the current status to the dangerous location.

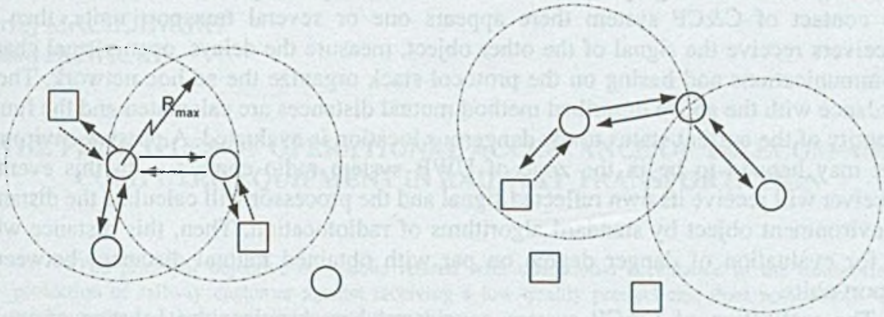

Fig.2. ITS objects clustering by radio contact: transport units are denoted by squares, the environment objects are denoted by circles

Figure 3 shows the functional diagram, illustrating the basic architecture of collision prevention system, using UWB signals to determine the distances and communication channels for ad-hoc computer network. For coarse evaluation of direction to the object four-section antennas are used here. Here we would like to note, that simplification may be achieved by using omni antennas, and the direction to the objects may be determined by changing the distances within several steps of time.

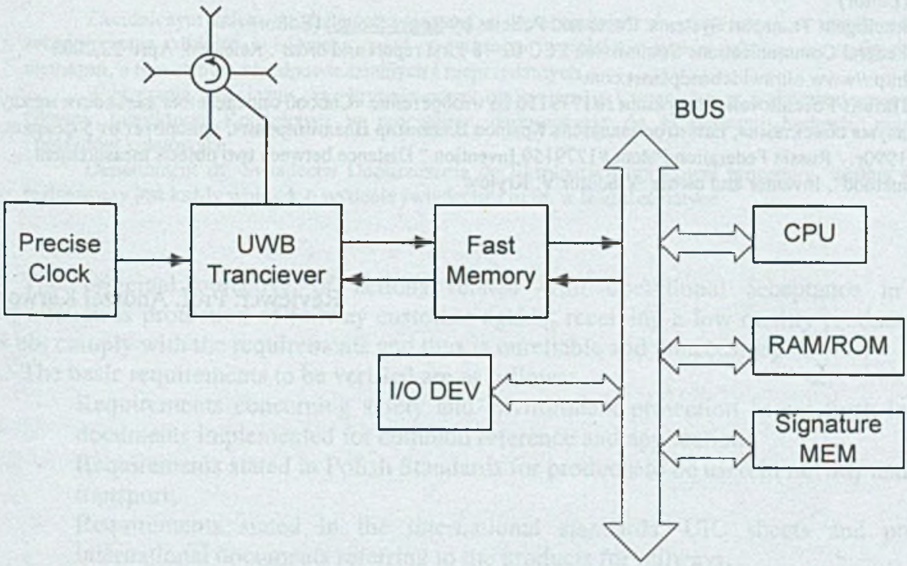

Fig.3. C&CP system functional diagram

Thus, the system functioning may be described by the following process. Transport units are moving under the control of their own autonomous controllers in compliance with the main ITS task. Every transport unit carries the equipment containing UWB transceiver, antenna system and C&CP processor. In accordance with exact time marks the transceiver emits a signal, containing synchronization code and object signature. If at the distance of radio contact of C&CP system there appears one or several transport units, then their transceivers receive the signal of the other object, measure the delays, open virtual channels of communications and basing on the protocol stack organize the ad-hoc network. Then, in accordance with the above described method mutual distances are calculated and the function of identity of the current status to the dangerous location is evaluated. A passive environment object may happen to be in the zone of UWB system radio contact. In this event, the transceiver will receive its own reflected signal and the processor will calculate the distance to the environment object by standard algorithms of radiolocation. Then, this distance will be used for evaluation of danger degree on par with obtained mutual distances between the transport units.

The realization of C&CP system considered here requires the solution of multiple technical and system tasks. As regards UWB transceiver, one of the main problems is to find UWB signal, efficient as the carrier of information with high speed, and simultaneously, as a radiolocation signal for the measurement of the distance to the environment objects. And its spectral distribution of power should be within the limits permitted by radio frequency regulatory bodies.

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Reviewer: Prof. Andrzej Karwowski