VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

LOCAL NAVIGATIONAL WEBS IN SURFACE CARRIERS CONTROL SYSTEMS

Viktor Vasilevich Shebolkov
Southern Federal University, Petrovskay Street, Russia
E-Mail: denisova.galina@gmail.com

ABSTRACT

The research results outlined in this paper were obtained with financial support from Ministry of Education and Science of the Russian Federation, as part of the execution of the project entitled "Establishment of high-tech production for the manufacture of complex reconfigurable systems of high-precision positioning of objects on the basis of satellite systems of navigation, local networks of laser and microwave beacons and technology MEMS", pursuant to decree of the government of the Russian Federation № 218 issued on April 09, 2010. The researches were carried out in SFU.

Keywords: local navigational web, control systems, traffic control, LNS segment structure.

1. INTRODUCTION

The questions on organization of local navigational systems and webs for problems of traffic control of surface carriers in critical sites of routes are considered with accuracy to decimeter in real time, at absence of satellite navigation signal. Options of such webs, data exchange modes between their components are offered.

In recent years in our country the radio navigational and telecommunication technologies have been invented on carriers rather widely which ultimate goal of application is a creation of uniform system of vehicles support in the cities' streets and highways of Russia and safety increase of their driving [1, 2]. The navigational provisions necessary for this problem solution should provide a creation and maintenance of artificial navigational fields with the given performances on precision, wholeness and spacial coverage. Technical requirements of customers to navigational security regulate, as a rule, the dimension of working zone, precision of definition of objects location, accessibility and wholeness of navigational information.

At global and regional levels the navigational fields form on the basis of satellite navigational systems and stations of differential correction [1, 2], concerning a local level - the satisfactory solution of this problem not exists in nowadays. The basic resort of definition of vehicles location at present time is the satellite navigation which ensures a location definition of moving objects with mean squared error 20÷30 m in usual condition and 5÷10m in differential mode. Such precision does not meet the demands of control systems of carriers on critical fields of automobile and railway routes where accuracy to decimeter of definition of transport objects location moving with velocities up to 150 km/h [2] is necessary. Besides in some local fields such as occluded buildings, tunnels, traffic intersections the accessibility of navigational satellites signals is limited. It forces to search for alternate options for deriving the navigational information.

One of the ways of considered problem resolution is to build-up the local navigational systems (LNS) and webs which would provide accessibility and the required precision of navigational information in those places of traffic where it cannot be made by means of satellite systems of navigation.

As local navigational systems (LNS) we will perceive further of the devices family which are creating and sustaining an artificial navigational area in the field of space in dimensions of some hundred meters.

For creation and maintenance of navigational field along the routes of surface carriers driving of some LNS by means of telecommunication inventory can be united into local navigational web and integrated with other navigational systems - satellite and inertial.

It's some attempts known of such local navigation systems creation of the most popular of which are the systems on the basis of pseudo satellites - the simulators of navigational satellites signals disposed on the ground surface which are used as reference radio navigational points [3-8]. Such LNS are used in systems of airplanes landing. Their appeal to the customers of navigational information consists in possibility to use them as navigational terminals of prevailing receivers of GLONASS or GPS signals. Their deficiencies - a high cost and complexity of organization of such systems operation, stipulated by necessity of using in them of high-precision system of uniform time, and also the low degree of interference immunity feature stipulated by both: noises, created by navigational satellites signals and relative simplicity of premeditated noises creation by possible malefactors.

Let's view the alternate options of building-up and organization of LNS performance for control systems of surface carriers.

VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

The most important demands to consider LNS are those follow:

Possibility of localization of created navigational fields on sites of served by them automobile and railway routes;

Precision of determination of objects coordinates moving with velocity up to 150 km/h - is not less than to 20÷30 cm;

Possibility of LNS integration with satellite and inertial resorts of navigation.

High degree of interference immunity feature concerning the mutual and organized noises;

A low cost of equipment and maintenance.

2. THE ANALYSIS OF POSSIBLE VERSIONS OF THE SOLUTION OF CONSIDERED ENGINEERING PROBLEM

The analysis of possible versions of the solution of considered engineering problem allows formulating the following basic principles of its decision.

a) The transport navigational web should be under the construction of separate segments serving the local fields on the traffic route in neighborhood of potentially dangerous sites of routes. These segments function independently from each other and can be united into uniform web which serves rather stretched field of the route.

b) Informational basis of such systems functioning is plurality of the reference (fiducial) radio navigational points disposed in each segment. Each segment is served by independent LNS defining the object coordinates of navigation concerning the fiducial points.

c) LNS serving the field different segments can be bound among themselves and with control office by informational web.

d) It is necessary to predict a possibility of identification by customer of navigational information of LNS signals serving the web segments and possibility of authentification of specified customer by web.

e) LNS shall not create the cross noises and should be the most inconvertible against the possible organized noises from potential trespassers.

The structure of local navigational web is given on Figure-1.

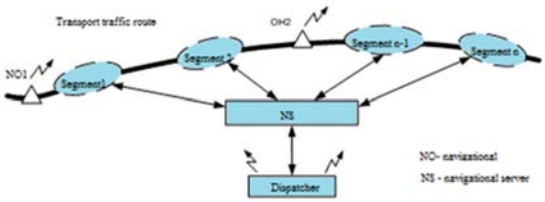

Figure-1. The structure of local navigational web.

Operation of web it is advisable to organize on principal "request -response". The vehicle - an object of navigation (NO) - in process of travel on the driving route sequentially gets to service zone of the web conforming segments. The NO determination fact in the conforming service zone can be erected by means of satellite navigational systems which precision is quite sufficient for this problem solution. At approaching the boundaries of the conforming service zone the NO sends a signal of navigational information request. LNS serving this segment, at reception of request signal fulfill the NO authentication procedure and at its positive result delivers to NO directly or through control office its coordinate and information for identification of this segment.

Use of request-response principle of navigational information deriving justifies itself for several reasons. First of all, it allows to increment sharply an interference immunity feature of web to action of premeditated noises and to reduce cross noises between the web segments. In addition there is a possibility of organization of authorized access to the web.

The most essential restriction of considered principle-a possibility of conflict situations appearance at serving by navigational web of several NO, is being in one segment. Such conflict situations can arise at simultaneous inflow into LNS of two and more requests for deriving of navigational information. Elimination of such situations can be reached by two trajectories: centralized regulating of sequences of indents from the dispatcher or method of casual access to mono-channel which is widely used at organization of work of local information webs [9, 6]. In this case as the mono-channel it is possible to consider the receivers of NO request signals, erected in the fiducial points [10, 11].

The first method requires the organization of trustful wireless communication channels for synchronization at equipment operating time of all NO, being within one segment. It is rather complicated from the hardware-software point of view and is more vulnerable from reliability point of view: at malfunctions in performance of synchronization system the LNS performance will appear paralyzed [12]. Application of this method is justified in cases when within one segment there can be large number of NO at the same time [13].

The second method is simpler than the first from the hardware-software point of view. For its embodying it

VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

is not required an additional wireless communication channels. The signal of request is radiated by NO only in that case when in the mono-channel there are no signals of request of other NO. It is more preferable from reliability point of view. [7, 8]. Application of this method is justified at small number of NO, at the same time being within one segment of web. Such situation is characteristic for the local navigational webs designed for guidance of carrier as simultaneous occurrence of more than 15÷20 vehicles moving with velocity 60÷120 km/h on dangerous site of the route in expansion 150÷200 m can be considered as situation unlikely. The structure of LNS serving one sector is shown in Figure-2.

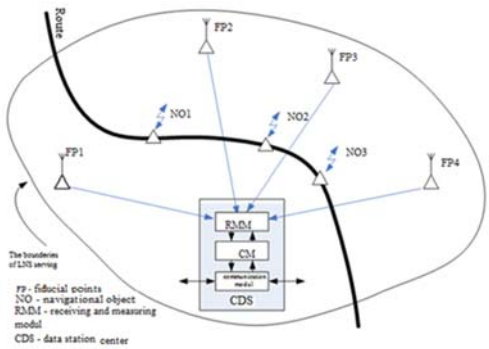

Figure-2. LNS segment structure.

In any case a simultaneous existence of several NO within one segment of the web call a delay in deriving of navigational information during which spacial NO location will vary. As the analysis show this factor does not influence essentially the measurement accuracy of NO coordinates.

Let's start from the segment dimension in some hundred meters, a motion speed of vehicles 60÷120 km/h and 15÷20 unities of vehicles at the same time are in it. At periodicity of request signals 0,5 seconds (during this time a NO can move on distance 8,3÷16,6 m) and holding time of one request making 50÷100 microsec the probability of coincidence in time of two request signals will compound microsec 0,002÷0,004. For delay time 50÷100 microsec the NO moving with velocity 60÷120 km/h will move on distance not more than 0, 0008÷0, 0016 m. Thus, to the error of coordinates determination, stipulated by inexactness of coordinate measuring with probability of 0,002÷0,004 the dynamic error can be added a quantity of 0,0008÷0,0016 m. It is obvious that this situation can be considered quite accepted.

The explained above allows to view as the basic method of decentralized casual access of customers to the navigational information.

For determination of NO coordinates in LNS it is expedient to use the phasic range-difference method with carrying out of measurements on beat frequency [14]. In this case in the fiducial points it shall be measured the differences in beat frequency signals phase, the differences in phase of two harmonic signals with close frequencies radiated by NO. The utilization in LNS of phasic range-difference method on beat frequency is justified by the following reasons:

- a possibility to spot a NO coordinates at small removals from the fiducial points, thus the exactitudes of determination of coordinates practically do not depend on distances between the NO and the fiducial points;
- a possibility to use in LNS the low-current narrowband signals that on the one hand increments an interference immunity feature of the web, and on the another - allows to lower of the level of cross noises between the LNS of the segments nearby;
- an acceptable precision and rather simple hardware embodying of the method.

The known deficiency of phasic methods - the many-valuedness of phase measurement and dependence of precision on the dimensions of served segment can be eliminated by means of multi-scaled methods. Thus it is necessary to take into consideration that the traditional options of multi-scaled methods used in phasic systems are grounded on the continuous radiation of navigational signals. They are unacceptable for request -response principal. Possible versions of the solution of this problem can be frequency variation of beats during one cycle of phase measuring, or a performance of phasic measurings simultaneously on several beat frequencies that guesses an application in LNS of multi-frequency harmonic signal instead of dual-frequency.

The symbolic circuit of build-up of customer navigational equipment is given in Figure-3.

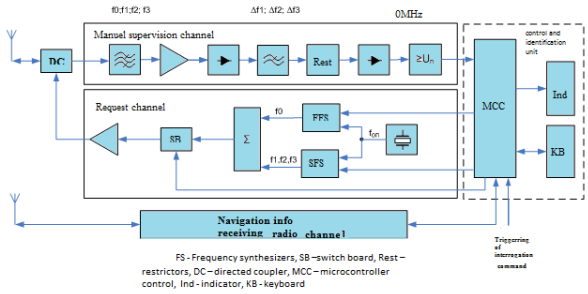

Figure-3. Navigational customer equipment.

The channel of request shapes a signal of navigational information request. The request is shaped by

NCA at simultaneous performance of two requirements: at first, from outside (for example, from satellite navigation system or the dispatcher) the triggering initiation command has arrived containing LNS code, secondly, the LNS should not be at this time busy serving another customer. The first requirement is provided by handling in MC of triggering initiation command, the second - by verification of presence on air of request signals from other users, i.e. by absence of restriction signal on outlet of manual supervision channel.

The structure of signal frame of navigational information request is given on drawing 4. The request begins with radiance of coded sequence of CFI designating the beginning of frame request. Then the code of navigational web (NWC) and code of identification of customer (CIC) are radiated. After that the signal of properly navigational signal is radiated. Depending on the chosen option of embodying of multi-scale method the signal of request represents either the dual-frequency (drawing 4a) or the multi-frequent (drawing 4a) harmonic signal. In the first case frequency of one of the harmonic signals varies in time, in the second - in the field of navigational signals some harmonic signals are radiated simultaneously. Frequencies of emitted signals are chosen so that from them it was possible to receive the required scaled frequencies necessary for navigational problem solution. The length of navigational signals field is chosen so that it was possible to ensure a precision of phasic measuring not less than 0, 5÷1 ° that at scaled frequency of 10 MHz without geometrical factor consideration it ensures a potential measurement accuracy of coordinates about 10 cm.

It should be noted that the use of multi-frequency signal of request allows to reduce several times the length of signal of request and respectively to increase a flow capacity of LNS at the price of the conforming loss of simplicity of its equipment.

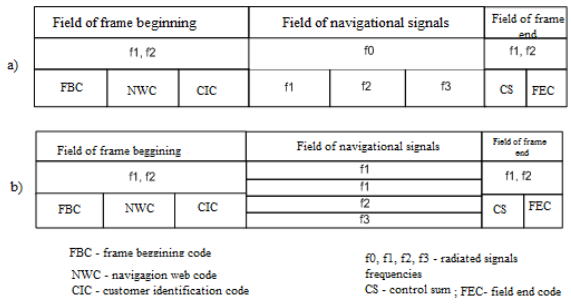

Figure-4. Structure of request signal frame.

Signals of request are received in the fiducial radio navigational points where the conforming receivers which identify request signal are erected; they form the signals of difference frequency (beat frequency) which on communication wired channels are transmitted into CDS. Use of wired channels clears itselves by several reasons. First of all - short range of CDS from the fiducial points (for LNS this range does not exceed several tens of meters), low cost and high noise immunity of such channels, and also simplification of electromagnetic compatibility problem solution at simultaneous inflow into CDS of several signals from the fiducial points with conterminous frequencies.

In CDS the signals normalization of arrived on amplitude is carried out, the necessary phasic measuring are fulfilled, the navigational problem is solved - the coordinates of navigation object are calculated - and the transmission of navigational information to its customers is organized: in data station, governing the motion of vehicles or directly onto object of navigation.

At selection of carrier frequencies it is necessary to take into consideration the following reasons: the gamut should correspond to regulating documents [15], it should be relatively free, the uptake of radio-wave of this gamut should depend feebly on atmospheric conditions, the dimensions of the antennas erected on object of navigation and in the fiducial points shall be as small as possible. It simplifies their installation on vehicles and in the fiducial points, masking and anti-vandal fulfillment.

CONCLUSIONS

The analysis of plurality of the numbered factors shows that in the greatest standard to the considered requirements are responding the two frequency ranges: 1215÷1300 MHz or 5460÷5470 MHz Necessary power of emitted signal of request is 5-10 MWt that allows at no directional radiance to provide apart 100÷300 m the power flux density of request signal about the order 10-10÷10-9 W/m^2.

REFERENCES

[1] Radio navigational plan of the Russian Federation. 2011. Approved by Order of Minpromtorg of Russia of September 2, 2008 No. 118, in edition of the Order of Minpromtorg of Russia of 2011. No. 1177. URL: internavigation.ru/documents/RNP2011.doc.

[2] The Order of Ministry of Transport of the Russian Federation of July 31, 2012 No. 285 "About the approval of requirements to the resorts of navigation functioning with use of navigational signals of GLONASS or GLONASS/GPS systems and designed for equipping of vehicles of M category utilized for commercial transportations of passengers, and of N category, utilized for dangerous loads transportation ". URL:garant.ru/products/ipo/prime/doc/70129002.

[3] Satellite radio navigational system of landing with use of pseudo satellites of RU 2439617, H04B7/185.

[4] Borsoyev V.A., Galeyev R.G., Grebennikov A.V. and Kondratyev, A.S. 2011. Use of pseudo satellites GLONASS/GPS in systems of aircrafts lands - Scientific messenger of the Moscow state engineering university of civil aviation.

[5] Cheung H.C. and Chan Y.T. 2004. Least squares algorithms for time-of-arrival-based mobile location. IEEE Transactions on Signal Processing. 52(4): 1121-1128.

[6] Lorincz K. and Welsh, M. 2005. MoteTrack: A Robust, Decentralized Approach to RF-Based Location Tracking. In: Strang, T., Linnhoff-Popien, C. (eds.) LoCA. LNCS. 3479: 63-82.

[7] Chen P.-W., Ou K.-S. and Chen K.-S. 2010. IR indoor localization and wireless transmission for motion control in smart building applications based on Wiimote technology. In: SICE Annual Conference.

[8] Medina A.V., Gómez J.A., Rivera O., Dorronzoro E. and Merino M. 2011. Fingerprint Indoor Position System based on OpenMAC. In: International Conference on Wireless Information Networks and Systems, Sevilla, Spain.

[9] Yu Y. and Silverman H.F. 2004. An improved tdoa-based location estimation algorithm for large aperture microphone arrays, Proceedings of IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP'2004). IV: 77-80.

[10] Olifer V.G. and Olifer N.A. 2010. Computer webs. Technology principles protocols. SPb. St. Petersburg. pp. 916.

[11] Tong H. and Zekavat S.A. 2007. A Novel Wireless Local Positioning System via Asynchronous DS-CDMA and Beam-forming: Implementation and Perturbation Analysis. IEEE Transactions on Vehicular Technology. 56(3): 1307-1320.

[12] Pourrostam J., Zekavat S.A. and Tong H. 2007. Novel Direction-of-Arrival Estimation Techniques for Periodic Sense Local Positioning Systems in Wireless Environment, proceedings IEEE Radar'07, 17-20 April, Boston.

[13] Konrad L. and Matt W. 2006. MoteTrack: A Robust, Decentralized Approach to RF-Based Location Tracking. To Appear in Springer Personal and Ubiquitous Computing, Special Issue on Location and Context-Awareness. pp. 1617-4917.

[14] Kinkulkin I.E., Rubtsov V.D. and Fabric M.A. 1979. Phasic method of coordinate's determination. - M: Sov. Radio, pp. 280.

[15] The resolution of the government of the Russian Federation of December 21, 2011 No. 1049-34. «About the approval of the Table of radio-frequency bands distribution between the radio services of the Russian Federation».