ANNOTATION

of the thesis on the topic:
«Development of the possibility of indoor positioning using low-energy Bluetooth signals»
presented for application of scientific degree of Doctor of Philosophy (Ph.D.) in specialty no. 6D071900 – «Radio engineering, Electronics and Telecommunications»

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Justification of the need for this research work

Improving positioning accuracy in closed rooms and resistance to interference in tasks with increased requirements is relevant. The lack of a single standard and the feasibility of research in this direction is based on a review of the literature and patent search.

General description of work

The work is devoted to the experimental and theoretical study of the possibility of positioning inside closed rooms using low-energy Bluetooth signals, as well as the comparison of the achievable positioning accuracy, resistance to interference between different approaches to positioning. The results of the performed physical experiments and modeling can be used in the design of new positioning systems in closed rooms. The thesis investigates the possibility of increasing the accuracy of positioning of objects in closed rooms, including mine workings, through the use of multifrequency radio signals. It is shown that the influence of multipath propagation of radio signals from the walls of structures, from obstacles of various origins, and the associated interference, can be weakened by using averaged attenuation values at different frequencies. The use of beacons with many frequencies can provide new possibilities for solving the problem of positioning objects in enclosed spaces.

Relevance of the topic

When deploying positioning systems in enclosed spaces, techniques with varying positioning accuracy and resistance to interference are used. Improving positioning accuracy and resistance to interference noise in tasks with increased requirements is urgent. The lack of a single standard and the feasibility of research in this direction is based on a review of the literature and patent search.

The aim of this work is to study the influence of LOS/NLOS conditions on the propagation of a radio signal and the possibility of reducing interference using a multifrequency transmission and receiving method for location determination tasks in enclosed spaces.

Research objectives

Check the difference in measurement accuracy when receiving a signal at one frequency from receiving a signal at several frequencies by combining the

measurement results of individual frequencies into one reading. Check the influence of various obstacles on the signal flow. Conduct computer modeling to identify the influence of adjacent antennas in the matrix of transmitting and receiving antennas. Carry out experimental measurements on the use of the matrix of transmitting and receiving antennas. Conduct computer modeling of radio wave propagation in conditions of interference and the influence of the multi-frequency method of reception and transmission, the "minimax" method, noncoherent accumulation, the height of the antenna of transmitters and receivers on the level of the received signal. Comparison based on root mean square errors.

Research objects

Bluetooth Low Energy beacons, USB beacons, spectrum analyzer, smartphone with standard software installed, transmitting and receiving antenna matrix.

Subject of study

Received Signal Strength Indication (RSSI), resistance to interference, positioning accuracy.

Research method

Independent design of microwave - generator and BLE - beacons with the ability to set broadcast frequencies and adjust the transmission power. Application of a multi-frequency transmission and reception method. Application of a matrix of transmitting and a matrix of receiving antennas.

The main provisions for the defense

The multi-frequency method of measuring the signal level at determining coordinates allows reducing errors in determining coordinates arising from interference;

The developed "minimax" method for determining the signal level allows tens of times to reduce the root-mean-square errors at measuring signal levels under interference conditions;

Reducing the height of the transmitter and receiver location relative to the floor of the room leads to a decrease in the magnitude of the error at measuring the signal level under interference conditions;

Noncoherent accumulation of measurement results at partial frequencies makes it possible to increase the accuracy of signal levels measurement even with a small bit resolution of analog-to-digital converters of receiving devices.

Scientific novelty

Analysis of publications and patent search on the topic of thesis shows that the proposed methods are original, new and aimed at solving problems of increasing the stability of the received signal level, which will improve the accuracy of the developed positioning systems in closed rooms.

The theoretical and practical significance of the work

The obtained experimental and computer results can be used when deploying positioning systems in enclosed spaces. The proposed methods of multi-frequency transmission and multi-frequency reception, the "minimax" method will reduce the

mean square errors, thereby stabilizing the signal level reading. The stability of the received signal level reduces the uncertainty in determining the coordinates. The proposal to reduce the height of transmitters and receivers in relation to the floor of the room is aimed at reducing the magnitude of the error when measuring the signal level under conditions of interference. This method is of practical use when applied to mobile robotic vehicles. An noncoherent accumulation of measurement results is proposed. This method will improve the signal-to-noise ratio. At a weak level of the received signal, at long distances, this method will eliminate the uncertainty in determining the coordinates.

Sources of research

The results of original scientific works are given in the list of used sources and the results of a patent search on this topic.

The personal contribution of the author lies in the fact that the main results of the physical experiment, numerical analysis and computer calculations, modeling were obtained personally by the applicant. The setting of tasks and discussion of the results were carried out in conjunction with scientific consultants.

Reliability of results

The reliability of the scientific conclusions of the work is confirmed by the reproducibility of the experimental results, the correspondence of the computer simulation data with the experimental results, the consistency of the results obtained with the theoretical premises and conclusions obtained by other authors in works similar in content, and the use of proven methods of numerical analysis.

Approbation of work

Based on the materials of the dissertation work: 1 article was published in a peer-reviewed journal in the Scopus database, 2 articles were published in publications recommended by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 2 articles were published as a result of a report at international scientific and practical conferences, 2 patents were received for a utility model, 1 certificate for an object of copyright has been received, 2 applications for a patent for an invention have been filed.

The structure and scope of the thesis

The dissertation consists of an introduction, five chapters, a conclusion, a list of references and contains a reference on patent search.