On the possibility of organizing communication for e-Navigation in the coastal zone using radio-technical posts of the vessel traffic control system

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Abstract. The concept of e-Navigation is to unify activities for the collection, integration, exchange, presentation and analysis of information on vessels and in coastal services through electronic technologies to improve the navigation safety, and the quality and efficiency of the relevant services. The generalized analysis of the obtained data is used to determine the appropriate actions in the prevailing conditions, to improve the process of the vessel's transition from berth to berth (in ports of departure and destination) and the corresponding services that ensure the safety of navigation, environmental protection, information exchange between intelligent transport systems. The basis for fulfilling the assigned tasks are three basic components of e-Navigation: vessel systems; coastal and satellite systems; communication infrastructure. The purpose of the paper is the possibility of applying broadband radio communications for unmanned navigation in the coastal zone. The research object is the analysis of broadband communication systems; the subject is the assumed range of the WiMAX radio communication zone. EMC Planner 1.1_170328 is used to simulate the anticipated WiMAX radio zone.

1. Introduction

The emergence of a unified information environment called e-Navigation makes it possible to supplement the existing vessel automation tools and collect them into a single information complex, which is a complex collection, integration, exchange, presentation, and analysis of marine information on the vessel board and in coastal systems by electronic means. Data from all sensors are integrated to reduce overall uncertainty and improve the quality and integrity of the perceived environment.

The use of broadband Internet access is assumed in e-Navigation. This is necessary to ensure an online mode for all participants in navigation and allows moving from ship automation to navigation automation, as well as to further unmanned navigation [1].

The development of computer systems and information technologies, their implementation in the field of shipping will create a single information network connecting all participants and every element of the maritime industry.

Reliable communication throughout the entire route is required for the vessel remote control. However, it seems to be possible since there is no communication coverage on many sea routes.
According to the coverage of the applied technology, maritime radio communication can be divided into two types: local and global. The local type includes communication at short (25-30 miles) distances, traditionally on ships in the near marine zone (area A1), which are engaged in maritime transport, use communication systems operating in the VHF range. VHF radio stations provide communication of a contemporary marine vessel with the operational dispatch service of the seaport. If a vessel is immersed in a high-speed broadband data network, it will be able to implement a huge number of various services that are not available without the use of expensive satellite communication systems at present.

The use of VSAT is being considered to provide global maritime broadband radio communications. However, VSAT application for solving issues of command and control of unmanned vehicles, and vessels in particular, seems unpromising. As a matter of fact, the use of VSAT is limited by low communication speed, problems with the channel budget when using geostationary satellites, high latency on the line “subscriber - spacecraft - communication center - spacecraft – subscriber” with the range of 0.5-1 s, and high cost and low reliability of VSAT equipment with scanning antenna. This problem may be solved after the start of the global satellite systems from SpaceX and OneWeb.

2. Broadband system analysis

We analyze the possibility of using broadband cellular communication systems 3G - GSM, LTE, WiMAX, licensed in many countries of the world to provide local maritime broadband radio communications in A1 sea navigation area.

GSM with the implementation of the HSPA and HSPA+ standards is ideally capable of developing speed up to 14.4 Mbit/s and 42 Mbit/s, respectively. The speed is much lower in reality. The communication range in the GSM standard can reach hundreds of kilometers. The maximum possible communication range in a standard GSM network is no more than 35 km. The communication range is determined by the Timing Advance (TA) coefficient, which serves to compensate for the delay in the propagation of the radio signal between MS (mobile stations) and BTS (base stations - BS) of cellular operators. Some GSM operators at base stations located on the seashore include a special mode due to which communication is feasible at a distance of up to 70 km [2].

LTE is the next generation of mobile communications after 3G and is based on IP technologies. The principal difference between LTE and its predecessors is the high data transfer rate. Theoretically, it is up to 326.4 Mbit/s for downloading and 172.8 Mbit/s for uploading information. In this case, the numbers of 173 and 58 Mbit/s, respectively, are indicated in the international standard [3]. LTE has support for handover and roaming with cellular networks of previous generations, all these devices are able to work in 2G/3G networks.

Fixed WiMAX networks are an implementation of the Broadband Wireless Access (BWA) technology of the IEEE 802.16-2004 standard [4]. The main purpose of these networks is to provide services for high-speed and high-quality wireless data, voice and video transmission over distances of several tens of kilometers to corporate and individual subscribers. The IEEE 802.16 standard defines the application at the physical (radio) layer of a broadband OFDM radio signal with multiple subcarriers; modern protocol of multiple (multistation) access Time Division Multiply Access (TDMA) and Scalable OFDM Access (SOFDMA) is used at the link layer.IP data transmission protocol, widely applied in most contemporary data transmission networks including the Internet, is used at the network (transport) layer in WiMAX networks.

The infrastructure of WiMAX networks is simpler than that of LTE networks. However, LTE networks are compatible with cellular communication standards of previous generations - GSM and UMTS. For instance, LTE networks can use the resources of GSM and UMTS networks for voice transmission, which are almost everywhere embedded in Russia. The above advantage is rather a disadvantage considering the requirements of information protection. The WiMAX 3.0 (IEEE 802.16n) standard is designed to replace the just adopted WiMAX 2 standard and will be even faster and more versatile. Network capacity should be 4 × 8 MIMO multichannel queuing with “channel cohesion.” Since the WiMAX 3.0 standard uses 10 channels of 6 MHz width at once, broadcast
stations have a great ability to transmit excellent quality video over a distance twice as long as WiMAX 2.

3. Calculation of the estimated range of broadband WiMAX 2 using radio technical posts of the vessel traffic control system (RTP VTCS) by the example of Novorossisk port

Each system is characterized by a parameter called System Gain which determines the maximum communication range. System Gain is defined as:

\[ \text{System Gain} = T_X - R_X \]  \hspace{1cm} (1)

where \( T_X \) – output power of the system transmitter; \( R_X \) – system receiver sensitivity.

The Link Budget equation is used to calculate the communication range. This equation relates the power levels at the receiver input RSSL and the output power of the transmitter \( T_X \) being at \( D \) distance from each other:

\[ \text{RSSL}_R = T_X + G_{TX} + G_{RX} - L_{RX} - L_{TX} - L_D \text{ dBm}; \]  \hspace{1cm} (2)

where \( T_X \) – transmitter output power, dBm; \( G_{TX} \) – transmitter antenna gain coefficient, dBi; \( G_{RX} \) – receiver antenna gain coefficient, dBi; \( L_{RX}, L_{TX} \) – UHF loss of signal power, respectively, in the receiver and transmitter, in the cable, connectors, etc.; \( L_D \) – loss in dB on the path of propagation of radio waves at a distance of \( D \) km [4].

In the conditions of Line Of Sight (LOS), which is typical for the location of radio technical posts (RTP) of vessel traffic control systems (VTCS), signal power loss in free space is calculated by the formula:

\[ L_D = 20 \cdot \log \left( \frac{4 \cdot \pi \cdot D}{\lambda} \right), \text{ dB}; \]  \hspace{1cm} (3)

where \( \lambda \) – wavelength.

Since the system maintains communication on modulation of 64QAM \( \frac{1}{4} \), if the signal level at the receiver input RSSL\(_R\) is higher the sensitivity level of \( R_X \), then according to Link Budget (2) equation following conditions should be fulfilled:

\[ \text{RSSL}_R - \text{FM} = T_X + G_{TX} + G_{RX} - L_{RX} - L_{TX} - L_D - \text{FM} \geq R_X \text{ dBm}; \]

\[ L_D = < T_X - R_X + G_{TX} + G_{RX} - L_{RX} - L_{TX} - \text{FM}; \]

where FM – Fade Margin (FM).

In real systems, the RSSL signal level exceeds the signal sensitivity level by some amount, called the fading margin FM due to radio multipath fading. In WiMAX systems with 64QAM \( \frac{1}{4} \) modulation of the OFDM signal, it is necessary to have FM equal to 1 dB, the value of FM 3 dB is used in practice.

Thus, for operation at a distance of \( D \) km, radio wave propagation losses should be less than:

\[ L_D = < \text{System Gain} + \gamma \text{ gain antennas} - \gamma \text{ UHF losses} - \text{FM} \text{ dB}; \]

The higher the System Gain and the lower the required FM fading margin are, the larger the communication channel budget that the system has and, accordingly, the greater the communication range is. The maximum possible theoretical WiMAX sensitivity is calculated excluding the use of diversity MIMO technology. Note that the diversity 2x2 MIMO technology which increases the System Gain and, accordingly, the Link budget by about 5 dB is applied in WiMAX systems. This indicator must be taken into account when calculating the channel budget. For modern WiMAX equipment of \( T_X = 26 \text{ dB}, R_X = 76 \text{ dBm at 64QAM \( \frac{1}{4} \)}, \) channel width of \( BW = 10 \text{ MHz}, \)

\( G_{TX} \) – integrated antenna 20 dB; \( G_{RX} \) – integrated antenna 20 dB; \( L_{RX}, L_{TX} \) – antenna is integrated with receiver and transmitter, feeder and connector losses are negligible, \( FM = 3 \text{ dB considering} \)
SystemGain MIMO + 5 dB, we obtain $L_D = -1.44 \, \text{dB}$. Inter-channel interference distorts the communication channel at sector boundaries; its level is accepted for: downlink channel – $IDL = 2 \, \text{dB}$, uplink channel – $IUL = 3 \, \text{dB}$. Given the above mentioned $L_D = -1.44 \, \text{dB}$, the communication range in accordance with (3) will be 75 km for the frequency ranges of 3.4-3.6 GHz permitted in the Russian Federation.

4. Modeling the anticipated WiMAX radio communication zone

We simulate the anticipated coverage area of the WiMAX radio communication standard using the RadioPlanner program, intended for calculation and optimization of coverage areas when designing cellular communication networks of the 3rd and 4th generation, by the example of VTCS of the Novorossisk port [5].

The simulation provided that the WiMAX equipment was located on the RTP VTCS without using cell towers and calculating the optimal arrangement of base stations and relayers to ensure ideal coverage of the radio communication zone for unmanned navigation.

5. Conclusion

The calculation of the estimated range of broadband WiMAX 2 using radio-technical posts of the vessel traffic control system (RTP VTCS) by the example of Novorossisk port showed that it was 75 km. The conducted modeling of the expected WiMAX radio communication zone by the example of RTP VTCS of Novorossisk port on the Gelendzhik-Taman route showed that the application of WiMAX equipment only on RTP VTCS Novorossisk will provide high-speed broadband Internet to all vessels in the A1 navigation zone for technical support of unmanned navigation. The expansion of the coverage area of the communication network means that some stations are outside the radio reception area, therefore, packet relaying through intermediate stations is required in order to deliver packets between them. Thus, expanding the network coverage area leads to the transition from a one-step network to a multi-step network.

References

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