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# A review of maritime communications systems and sensors for offshore applications

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**Abstract**. In the last period (last 3 years) the maritime domain, especially the sea transportation and fossil resources exploitation became the most important aspects of the international politics and our lives. Because of the COVID19 situation and now the conflict between Russia and Ukraine, the maritime domain was pushed to its limits. What a few years ago was a safety area of navigation, now this one can be transformed very quickly in a dangerous one. It is important to develop fast, systems for monitoring sea areas and platforms of intervention in case of distress situations. To have a real-time system of monitoring and intervention on sea it is mandatory to have redundant maritime communications. The article presents the most relevant publications related to maritime offshore applications and communications that support them.
**Keywords (3–5):** maritime, offshore, communications, sensors, review.

## 1. Introduction

The study contains bibliography research of the newest data transfer (communications) technologies that can be implemented in maritime domain, especially in offshore areas. Offshore areas must be understood here as line-of-sight communications.

Of course, everyone wants to have a communication system with global coverage, no limit traffic, low power consumption, portability/mobility, high speed data transfer, low cost or if it is free, it is perfect. Free means that you pay only for initial investment in hardware equipment and after that you pay and annually fee for frequency utilization license.

As far as we know and studied a system which has the advantages described above, as you may have already guessed, doesn't exist. But, with this trend of developing new satellites constellations and combination between low-medium and geostationary satellites constellations, in the future, there are real chances to have this kind of system for vital activities as: Search and Rescue, Maritime pollution, Catastrophic Awareness systems etc; but also, for commercial and routine communications.

In the following pages we tried to resume all important communications applications and systems that can be used in offshore areas for distress, pollution and radiation hazards situations. We researched on international data platforms which are recognized as professional tools for researchers all around the world. Any research in developing a new maritime communication system starts with collecting of information about state of the art of this kind of systems.

Our system will not interfere with GMDSS system and procedures. The communication system will help on site communications and transmission in real time of data between intervention ship and shore coordination teams. The system will be able to integrate ship's sensors (including pollution and radiation), video conference system and voice communications. The system will have three main subsystems: satellite, mobile and WiFi.

## 2. Satellite applications

For offshore waters satellite applications/systems are, in our opinion, only for redundancy of the communications systems. The main reason for that is the high cost of data transfer and hardware which provides high speed data transfer.

Of course, satellite communications can help maritime domain in many ways. The firs application that we found it interesting was written by Høye et al. in 2008 and it is about *Space-based AIS for global maritime traffic monitoring* – the idea of authors is to combine the AIS (Automatic Identification System) with LRIT (Long Range Identification and Tracking) for optimizing the maritime surveillance and safety. [1] With proper sensors on specific vessels, the LRIT can be used for monitoring almost everything. Of course, if you have access to internet via satellite on a vessel you can develop your own data acquisition system.

Another article which presents ideas for AIS implementation with Satellite system is *Generalized mechanism of SOTDMA and probability of reception for satellite-based AIS*. In this paper it is proposed an algorithm to model observations of satellite based for SOTDMA (Self Organized Time Division Multiple Access) systems. You cand find valuable information about AIS systems, space-based AIS and the simulation of the performance of the proposed method. The particularization of the problem is summarized in the Figure 1. The numbers represent ships and letters represents areas. In this case the center ship (1) can communicate with ships 2,3 and 5, also vice-versa, but ship no. 4 is out of the satellite field of view so she cannot "see" on AIS the other ships. The proposed methodology will fix this problem [2].

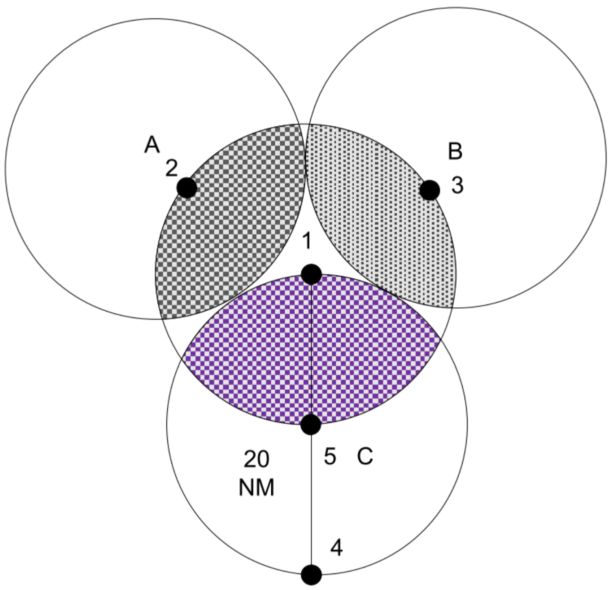


Figure 1. Multiple SOTDMA regions. Ship no. 4 is out of the satellite field of view.

A good way to start your bibliographic research is to find articles like "a review of" or "the state-of the art" and so on. For satellite communications systems applied to maritime domain, more exactly to oceanography large scale monitoring, we recommend to have a look at *On small satellites for oceanography: A survey* [3]. There are presented applications of VSAT (Very Small Aperture Terminals) in ocean studying. In the article the VSAT systems are called micro and nano-satellites which means that the mass is smaller than 100 kg and short period of development. These systems are designed, developed and tested by academic departments in order to have communications with observation robotic assets in ocean. Also, the article contains a suggestion on how to use RADAR observations, with a special attention on SAR (Synthetic Aperture Radar).

In *Satellite Communication - A Review* [4] a short history of the satellite is presented, why we use the satellite for communications and what is the orbital model. How the satellites are in orbit and the types of orbits. How an artificial satellite is launched and what components are needed to design satellites.

For a better understanding of satellites systems as: fundamentals, orbits and trajectories, launch and in-orbit operations, hardware, communication techniques, multiple access techniques, and link design fundamentals; we recommend the book *Satellite technology: principles and applications* [5]

An interesting application of satellite communication we found also at *Satellite data for the offshore renewable energy sector: Synergies and innovation opportunities* [6] where is discussed to domain of offshore windfarms and ocean satellite observations. There are presented also the ocean variables that can pe provided by satellites, performances of satellite and how the data is processed and integrated.

Between the terrestrial and maritime communications there are many differences. The most important one is the electromagnetic waves propagation properties which are explained in *A survey of maritime communications: From the wireless channel measurements and modeling perspective* also is presented a survey of maritime communications with an approach in the wireless channel modeling and measurements [7]. These differences are reflected in performance of data transmission and must be well documented for development of specific applications in certain areas. An example of testing satellite communications is presented in *Testing of DiffServ performance over a U.S. Navy satellite communication network* [8].

Satellite constellations are designed using methods for a simple zonal or global, continuous or discontinuous coverage connected areas on the Earth's surface. For better performance the new satellite constellations must have more complex coverage of a geographic region. That means, at any time, the satellite can provide instantaneous access. An idea to obtain this is a two-dimensional space application for maps of the satellite constellation and coverage requirements and is presented in *Satellite constellation design for complex coverage* [9]. Right ascension of ascending node and argument of latitude form the two-dimensional space. A polygon represents the visibility requirements of each region and uniform moving grid represents satellite constellation. The idea presented is that at least one grid vertex must overlay with a polygon.

The maritime Internet of Things cannot exist without satellite machine-type communication. The implementation of such a technique it's hard to be realized because of the global broadcasting nature, resulting in many interferences. ITU struggles to find solution for these systems. To get in contact with this subject and to study mathematical analysis of the interferences we recommend the article *Satellite Machine-Type Communication for Maritime Internet of Things: An Interference Perspective* [10].

## 3. Terrestrial communications applications

One of the newest technologies in this domain is the visible light communication (VLC). VLC is immune to electromagnetic interference, provides high data security, and utilizes unregulated visible light spectrum, showing promise as a potentially cheaper alternative to existing radio frequency (RF) based technology. Recent advances in solid-state technologies and semiconductor materials have enabled the development of efficient light-emitting diodes (LEDs) and laser diodes (LDs) which are used as transmitters in a VLC system. Indoor tests show good results with speeds of 10s of Gbps. For outdoor communications the researchers struggle with environmental factors, unwanted lights, non-line of sight communication, directional radiation pattern and frequent fragmentation. This information is taken from article Visible light communication for intelligent transportation systems: A review of the latest technologies [11]. The article presents the review of VLC in order to implement in the Intelligent Traffic Surveillance for cars. In our opinion this system can be implemented very well in offshore communications systems.

The WiFi technology offers the best performances for communications applications at a low cost of development and data traffic. Unfortunately, at sea the GHz frequencies are attenuated fast due to humidity environment. For short distances and proper WiFi networks this technology can be used on offshore application. One type of WiFi networks for maritime domain is presented in Figure 2, from the article Joint Multicast Beamforming and Relay Design for Maritime Communication Systems [12]. In order to optimize the system, the authors propose a mathematical model which shows where a relay solution is better that the classical access point one.

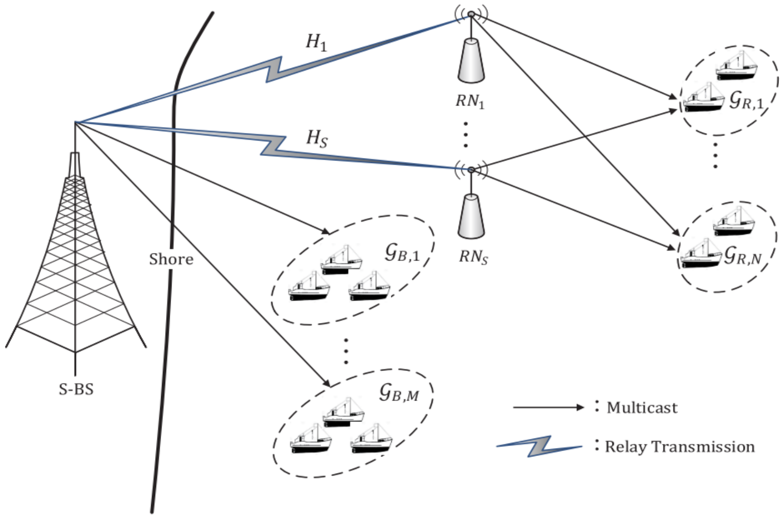


Figure 2. Illustration of a maritime multicast scenario including one S-BS, multiple RNs, and vessel users.[12]

Another interesting idea is to use an air relay for shore to ship communications. In the article *Wireless channel models for maritime communications* [13] is presented a survey with the most notable differences for modeling and channel characteristics for communications using air relaying and surfaces channel links. The conclusion of the article is that the location characteristics (propagation properties) and sparse are the most important and distinctive variables of the maritime wireless channels. The main idea of the article is presented in Figure 3.

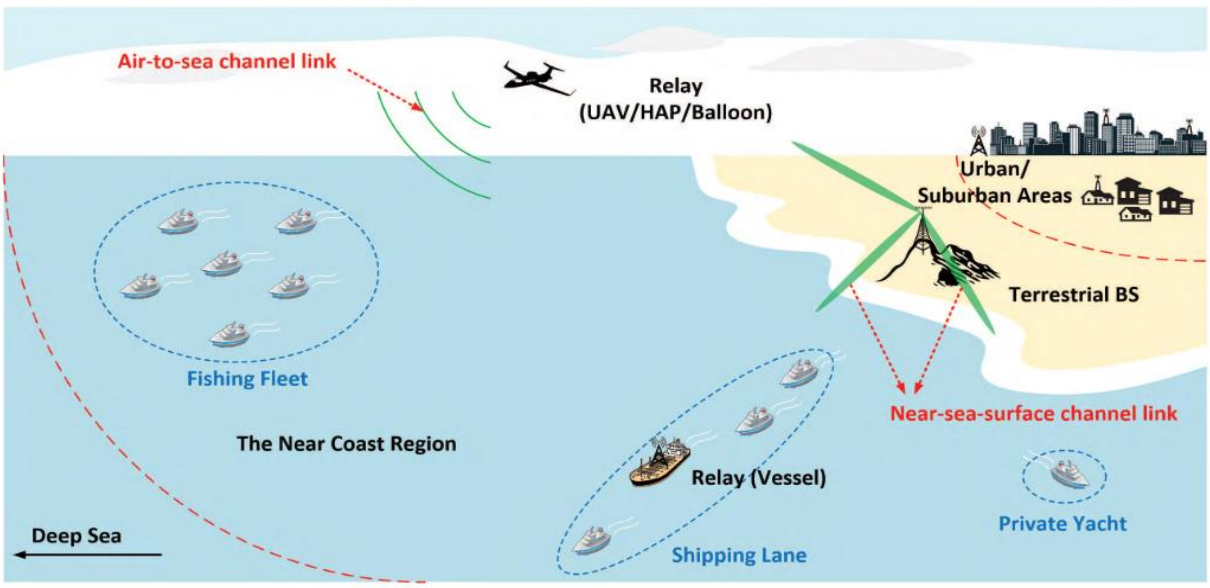

Figure 3. An illustration of the integrated air-ground-sea maritime communication network. [13]

As we did at satellite communications for experimental result, we found a representative WiFi experiment for maritime communications in the article *Applying maritime wireless communication to support vessel monitoring* [14]. The authors had the same idea to use WiFi access points to delivery communications to ships in the vicinity of shore. More then that, they made an experiment for measure the signal strength variation to distance. The results are presented in Table 1.

Table 1. Signal strength depending on distance between Base Station and Customer Premises Equipment

| Distance | | | |
|---|---|---|---|
| (km) | High of Antenna Transmitter BS (m) | High of Antenna Receiver CPE (m) | Strength of signal (dBm) |
| 1 | 5 | 2 | -58 |
| 2 | 5 | 2 | -64 |
| 4 | 5 | 2 | -70 |
| 5 | 5 | 2 | -72 |
| 6 | 5 | 2 | -73 |

What is not specified in the article are details about the weather, period of year and day, temperature, humidity and so on. But, as we said earlier, these parameters vary from one area to another. The conclusion we made so far is that every project of maritime communications must have a modeling and experimental stage for area of implementation.

Of course, in the future there will be more maritime communications solutions due to accessibility of using Software Defined Radio boards. The academic domain will come up with specific applications for broadband communications in maritime domain by using SDRs. The 5G technologies have been developed using SDR[12], [15]; it's clear that 6G technologies will be developed in the same manner[7], [16], using SDR and MIMO communications [17].

A survey of unmanned aerial and water vehicle which use wireless communications is presented in [18]. The focus is on the main features to take into account for designing unmanned aerial and aquatic vehicle networks with the aim to help the reader to transfer valid approaches and techniques between aerial and aquatic applications.

Internet of things[15], [19]–[21] is known as Internet of Maritime Things (IoMT) in marine domain. For offshore application it will be the most valuable system in the next period. An application of this is a platform that supports high-rate communication for long-range in order to monitor remotely and online to marine water quality [22].

## 4. Conclusions

The maritime domain is one of the most important domains after the corona virus crisis and the escalation of conflict between Russia and Ukraine. What was a safety area of navigation now can very easy become a dangerous one. In order to maintain the operability of sea-transportation (more than 90% percent of the word goods transportation [23]) it is necessary to develop monitoring systems[1], [22], [24]–[31] as well distress or urgency intervention platforms. In the paper are presented the most relevant articles, ideas, surveys and researchers which are related to maritime offshore communications systems and monitoring/intervention systems.

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**References**

[1] G. K. Høye, T. Eriksen, B. J. Meland, and B. T. Narheim, "Space-based AIS for global maritime traffic monitoring," Acta Astronaut., vol. 62, no. 2–3, pp. 240–245, Jan. 2008, doi: 10.1016/j.actaastro.2007.07.001.

[2] A. Harchowdhury, B. K. Sarkar, K. Bandyopadhyay, and A. Bhattacharya, "Generalized mechanism of SOTDMA and probability of reception for satellite-based AIS," *CODEC 2012 - 5th Int. Conf. Comput. Devices Commun.*, 2012, doi: 10.1109/CODEC.2012.6509332.

[3] A. G. C. Guerra, F. Francisco, J. Villate, F. Aguado Agelet, O. Bertolami, and K. Rajan, "On small satellites for oceanography: A survey," *Acta Astronaut.*, vol. 127, pp. 404–423, Oct. 2016, doi: 10.1016/j.actaastro.2016.06.007.

[4] D. Trivedi and D. Gadhavi, "Satellite Communication-A Review," 2015.

[5] A. K. Maini and V. Agrawal, *Satellite technology : principles and applications*. .

[6] E. Medina-Lopez *et al.*, "Satellite data for the offshore renewable energy sector: Synergies and innovation opportunities," *Remote Sens. Environ.*, vol. 264, p. 112588, Oct. 2021, doi: 10.1016/j.rse.2021.112588.

[7] W. Chen, C. Li, J. Yu, J. Zhang, and F. Chang, "A survey of maritime communications: From the wireless channel measurements and modeling perspective," *Reg. Stud. Mar. Sci.*, vol. 48, p. 102031, Nov. 2021, doi: 10.1016/j.rsma.2021.102031.

[8] D. A. Barsaleau and M. Tummala, "Testing of DiffServ performance over a U.S. Navy satellite communication network," *Proc. - IEEE Mil. Commun. Conf. MILCOM*, vol. 1, pp. 528–534, 2004, doi: 10.1109/MILCOM.2004.1493321.

[9] Y. Ulybyshev, "Satellite constellation design for complex coverage," *J. Spacecr. Rockets*, vol. 45, no. 4, pp. 843–849, 2008, doi: 10.2514/1.35369.

[10] T. Xia, M. M. Wang, and X. You, "Satellite Machine-Type Communication for Maritime Internet of Things: An Interference Perspective," *IEEE Access*, vol. 7, pp. 76404–76415, 2019, doi: 10.1109/ACCESS.2019.2919253.

[11] K. Shaaban, M. H. M. Shamim, and K. Abdur-Rouf, "Visible light communication for intelligent transportation systems: A review of the latest technologies," *J. Traffic Transp. Eng. (English Ed.*, vol. 8, no. 4, pp. 483–492, Aug. 2021, doi: 10.1016/J.JTTE.2021.04.005.

[12] R. Duan, J. Wang, H. Zhang, Y. Ren, and L. Hanzo, "Joint Multicast Beamforming and Relay Design for Maritime Communication Systems," *IEEE Trans. Green Commun. Netw.*, vol. 4, no. 1, pp. 139–151, Mar. 2020, doi: 10.1109/TGCN.2019.2947469.

[13] J. Wang *et al.*, "Wireless channel models for maritime communications," *IEEE Access*, vol. 6, pp. 68070–68087, 2018, doi: 10.1109/ACCESS.2018.2879902.

[14] Z. Zainuddin, Wardi, and Y. Nantan, "Applying maritime wireless communication to support vessel monitoring," *Proc. - 2017 4th Int. Conf. Inf. Technol. Comput. Electr. Eng. ICITACEE 2017*, vol. 2018-January, pp. 158–161, Jul. 2017, doi: 10.1109/ICITACEE.2017.8257695.

[15] R. Akeela and B. Dezfouli, "Software-defined Radios: Architecture, state-of-the-art, and challenges," *Comput. Commun.*, vol. 128, pp. 106–125, Sep. 2018, doi: 10.1016/j.comcom.2018.07.012.

[16] G. R. Maccartney and T. S. Rappaport, "Millimeter-Wave Base Station Diversity for 5G Coordinated Multipoint (CoMP) Applications," doi: 10.1109/TWC.2019.2913414.

[17] S. N. Sur and R. Bera, "Intelligent reflecting surface assisted MIMO communication system: A review," *Phys. Commun.*, vol. 47, p. 101386, Aug. 2021, doi: 10.1016/J.PHYCOM.2021.101386.

[18] J. Sánchez-García, J. M. García-Campos, M. Arzamendia, D. G. Reina, S. L. Toral, and D. Gregor, “A survey on unmanned aerial and aquatic vehicle multi-hop networks: Wireless communications, evaluation tools and applications,” *Comput. Commun.*, vol. 119, pp. 43–65, Apr. 2018, doi: 10.1016/J.COMCOM.2018.02.002.

[19] J. Zhang, M. M. Wang, T. Xia, and L. Wang, “Maritime IoT: An Architectural and Radio Spectrum Perspective,” *IEEE Access*, vol. 8, pp. 93109–93122, 2020, doi: 10.1109/ACCESS.2020.2990830.

[20] M. Cho, H. R. Cho, and C. Kwa, “A Study on the Method of IoT-based Navigation Aids Management,” pp. 55–58, Jun. 2015, doi: 10.14257/ASTL.2015.98.15.

[21] D. Palma, “Enabling the Maritime Internet of Things: CoAP and 6LoWPAN Performance over VHF Links,” *IEEE Internet Things J.*, vol. 5, no. 6, pp. 5205–5212, Dec. 2018, doi: 10.1109/JIOT.2018.2868439.

[22] Y. Song *et al.*, “Internet of Maritime Things Platform for Remote Marine Water Quality Monitoring,” *IEEE Internet Things J.*, 2021, doi: 10.1109/JIOT.2021.3079931.

[23] “How ship technology is evolving in the 21st century.” http://www.21stcentech.com/transportation-part-4-the-marine-challenge-ships-and-routes/ (accessed Feb. 20, 2015).

[24] L. Elkins, D. Sellers, and W. R. Monach, “The autonomous maritime navigation (AMN) project: Field tests, autonomous and cooperative behaviors, data fusion, sensors, and vehicles,” *J. F. Robot.*, vol. 27, no. 6, pp. 790–818, Nov. 2010, doi: 10.1002/ROB.20367.

[25] T. Tares, H. Greidanus, G. Jurquet, and P. Helie, “Wide maritime area airborne surveillance SoS,” *2009 IEEE Int. Syst. Conf. Proc.*, pp. 123–126, 2009, doi: 10.1109/SYSTEMS.2009.4815784.

[26] K. Fedra and L. Winkelbauer, “A hybrid expert system, GIS, and simulation modeling for environmental and technological risk management,” *Comput. Civ. Infrastruct. Eng.*, vol. 17, no. 2, pp. 131–146, 2002, doi: 10.1111/1467-8667.00261.

[27] “An integrated maritime reasoning and monitoring system | IEEE Conference Publication | IEEE Xplore.” https://ieeexplore.ieee.org/document/6289963/references#references (accessed Apr. 20, 2022).

[28] C. Albaladejo, P. Sánchez, A. Iborra, F. Soto, J. A. López, and R. Torres, “Wireless sensor networks for oceanographic monitoring: A systematic review,” *Sensors*, vol. 10, no. 7, pp. 6948–6968, Jul. 2010, doi: 10.3390/S100706948.

[29] T. Eriksen, G. Høye, B. Narheim, and B. J. Meland, “Maritime traffic monitoring using a space-based AIS receiver,” *Acta Astronaut.*, vol. 58, no. 10, pp. 537–549, May 2006, doi: 10.1016/J.ACTAASTRO.2005.12.016.

[30] D. Moroni, G. Pieri, O. Salvetti, and M. Tampucci, “Proactive marine information system for environmental monitoring,” *MTS/IEEE Ocean. 2015 - Genova Discov. Sustain. Ocean Energy a New World*, Sep. 2015, doi: 10.1109/OCEANS-GENOVA.2015.7271533.

[31] V. L. Timchenko, D. O. Lebedev, E. A. Kuklina, and I. V. Timchenko, “Robust-optimal control system of quadrocopter for maritime traffic’s monitoring,” *2017 IEEE 4th Int. Conf. Actual Probl. Unmanned Aer. Veh. Dev. APUAVD 2017 - Proc.*, vol. 2018-January, pp. 192–195, Mar. 2018, doi: 10.1109/APUAVD.2017.8308807.