

Architecture of the regional satellite augmentation system for maritime applications

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ABSTRACT

This paper describes architecture of regional satellite augmentation system (RSAS) in the function of the maritime space communications, navigation and surveillance (CNS) and global navigation satellite systems (GNSS) networks for enhanced safety and surveying of oceangoing ships, management and tracking of cargo, security of Mariners onboard commercial and passenger ships, yachts, sea platforms and other types of craft. The RSAS network are designed to improve vessel management and transport operation because of the enormous expansion of the world's merchant fleet. However, this network with a special ship tracking system can also improve the protection of merchant ships and their crews against piracy, violence, robbery and terrorist attacks. The international maritime organization (IMO) and shipping flag states have project for development of the international ship and port security (ISPS) and design to implement an approaching and port control system (APCS) by special code for all merchant vessels including determination, tracking and positioning of all ships movements in and out of the seaport area. The Maritime RSAS and CNS systems are integration components of the global satellite augmentation systems (GSAS) of two operational GNSS-1 military networks, such as the US global position system (GPS) and Russian global satellite navigation system (GLONASS). In this paper are also introduced the special effects of the ships RSAS networks and coastal movement guidance and control (CMGC) system for maritime application at sea and in seaports areas.

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1. INTRODUCTION

The present operational GNSS-1 networks are constructed by the basic applications for position, velocity and time (PVT) and additional positioning information obtained from US GPS and Russian GLONASS military spacecraft. Both solutions are formations of the first generation GNSS-1 networks that provide accurate positions of about 30 meters implementig simplified GPS or GLONASS receivers (Rx) onboard ships, which due to some anomalies cannot be used as the only means of positioning for ocean going vessels all all moving objects at sea. Practically GPS and GLONASS satellite systems utilized autonomously cannot respond to the extremely important requirements for integrity, continuity, accuracy and availability (ICAA) in particular for ship traffic control (STC) and ship traffic management (STM) for improved maritime CNS solutions, which are insufficient for enhance ships control, positioning, navigation and movement in seaports. In order to provide significant improvements over the GNSS-1 networks, it will be necessary to design the GNSS and their RSAS integration portions [1-3].

2. COMPARISON OF THE CURRENT AND NEW MARITIME CNS SYSTEMS

The high performance objectives for maritime space (radio and satellite) CNS solutions are mostly practiced during crossing the oceans, sailing near coastlines, at anchorages, in inland waters and within seaport areas. The precision positioning demands of oceangoing ships is 1 and 2 miles related for high seas navigation, 0.25 miles for coastline sailing and about 8-20 miles operations at the anchorage and at the seaports. Anyway, if there is no RSAS service in a particular region, the GPS or GLONASS networks are able to meet sufficiently accurate navigational and safety demands during ocean or shoreline sailing. However, for sailing of ships during significant bad weather situation, enormous reduced visibility, and in sailing areas with extremely increased operations of ships, at anchorages and in ports, new techniques of the CNS systems must be deployed for enhanced collision avoidance. The previous or current and modern maritime space (radio and satellite) CNS applications are proposed as future integration with newly developed RSAS networks on northern hemisphere and projected on Southern Hemisphere due to the formation of a new system for improved ship traffic control (STC) and ship traffic management (STM), during all stages of sailing, at anchorages and in harbours [4-6].

2.1. Maritime communication subsystem (MCS)

The worldwide shipping companies and operators have used over the decades and today are still using shipborne conventional voice and data radio communication systems on the very high frequency (VHF) band for short-range at distance of about 60 miles, medium frequency (MF) band for medium-range at distance of about 150-250 miles and high frequency (HF) band for long-range distances up to 3000 miles during oceanic intercontinental voyages. The ship radio station (SRS) onboard oceangoing vessels are communicating with coast radio station (CRS) and ship traffic control (STC)/ship traffic management (STM) at VHF band via direct-line of sight (LOS), at MF-band and HF-band via the ionosphere refraction, which scenario is in Figure 1. Shipborne VHF equipment is radio communication system consisting transmitter and receiver installed onboard vessels, which is in use for voice and data transmissions between vessels, vessels and coast, such as connections with seaports authorities), and in special situation between vessels and airplanes. The VHF radio uses frequency modulated (FM) links in the very high frequency (VHF) at 156 to 174 MHz. The International Telecommunication Union (ITU) has an official nomenclature for VHF-band known as VHF maritime mobile band. Otherwise, the certain governments of the Nordic countries are using some special VHF channels at L and F-band (from 155.5 to 155.825 MHz) for installations onboard for use on fishing and cruise vessels. The transmission power of VHF radio is up to 25 watts with range up to 100 miles during the night.

The VHF two-ways transmission links in coastal waters between ships SRS and CRS terminals can be interfered with very high mountains and cause significant problems for radio communications. Thus, the HF radio links between SRS and CRS terminals sometimes cannot be performed due to the lack of the required HF-band, increased interference, unfavorable propagation conditions, unstable frequency band, poor wave transmission and very bad weather with increased thunderstorms. Thus, the present maritime radio communication solutions between oceangoing ships and offices at shore are conducted via VHF radio through direct link over horizon (LOS), and for medium MF and long range HF are using the ionospheric refraction effects for digital voice and data radio frequency (RF) bands, known as maritime radio communications (MRC) network, which previous or present radio transmission network is depicted in Figure 1 (a).

The MRC system is providing ships radio communications on VHF, MF and HF RF-bands via CRS terminals to connect different offices at shore, ship owners, port authorities, STC and STM terminals. In certain congested parts of the globe the MRC transmission network is limited, because of very preoccupied frequency bands, additional radio bands are not provided, successful radio traffic in the area with very bad meteorological situation depends on the propagation and interference effects and sometimes due to the distress alert situation commercial radio traffic is decreased. The VHF radio onboard oceangoing ships is also dedicated for distress alert, safety, security and emergency communications. Except voice communications, radio data transmission have recently also been used, primarily for voyage plan and global weather (WX) and navigation (NX) warning. In addition to the data transfer for the navigation bridge and cabins, telephone service for crewmembers and passengers were also employed onboard ships. Finally, presently all ships use conventional radio and satellite navigation instruments, but still use radar for surveillance facilities. The STC/STM facilities and general communication system were recently upgraded with implementation of maritime satellite communication (MSC), which is illustrated in Figure 1 (b). This system provides voice, data and video over IP (VDVoIP) via satellite data links (SDL), satellite automatic dependent surveillance-broadcast (SADS-B), global ships tracking (GST), long range identification and tracking (LRIT) and voice between ship earth station (SES) and coast earth station (CES) via geostationary earth orbit (GEO) spacecraft.

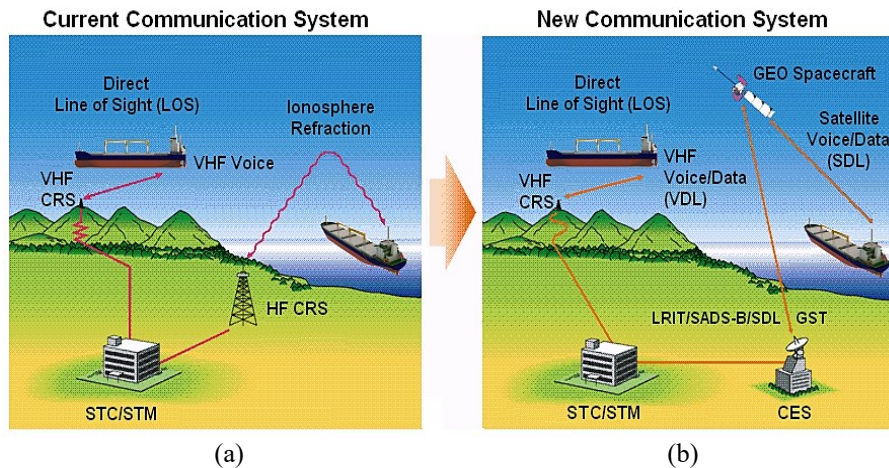


Figure 1. Maritime communication subsystem for CNS/STM system;
(a) current system and (b) new communication system

All SES transceivers perform interactive telephone (voice) service, transfer of different speed data, facsimile, telex and pictures via Inmarsat GEO spacecraft, CES infrastructures and current terrestrial telecommunication network (TTN) to the land customers. The network operations centre (NOC) is situated at Inmarsat headquarters in London, while Inmarsat ground network (IGN) is operation together with network control centre (NCC), satellite control centre (SCC), network coordination stations (NCS) and tracking, and telemetry, command (TT&C). Otherwise, IGN infrastructure is associated to rescue coordination centre (RCC) in case of distress alert situation. The Inmarsat MSC system can connect shore users via mobile integrated services digital network (ISDN) or an always-on mobile packet data service (MPDS), Broadband ISDN (B-ISDN), asynchronous transfer mode (ATM), universal mobile telecommunication systems (UMTS) and general packet radio service (GPRS). In addition to the Inmarsat MSC system providing SDL service, new GEO satellite constellations are used to provide the latest DVB-RCS facilities, such as VDVoIP service and SADS-B system, which modern MCS network is shown in Figure 2.

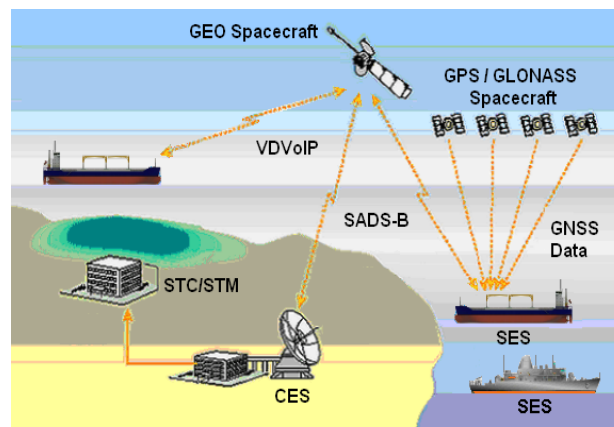


Figure 2. Modern MCS Network [4]

On the other hand, as depicted in Figure 2, the RSAS networks are integrating current MCS solutions with GNSS-1 infrastructures to transfer PVT signals to embedded GPS or GLONASS receivers onboard ships and SES transceivers. However, in the return direction all PVT and all data obtained from onboard ships GNSS-1 (GPS or GLONASS) receivers can be transferred by SES transmitters manually or automatically to STC/STM via GEO spacecraft and CES infrastructures. The implemented trade and defense MCS infrastructures and systems are of great importance for the following reasons:

- a. To facilitate maritime satellite communication links between different oceangoing vessels and shore infrastructures, and communication system between ships alone via GEO spacecraft transponders;

- b. To transmit augmented and not-augmented PVT and other information from ships to STC terminals via GEO spacecraft communication transceiver. This data is extracted from GPS or GLONASS onboard receivers and processed for ship navigation utilities or external solutions;
- c. To transmit augmented and not-augmented PVT and other data from ships to STC terminals via GEO satellite communication transponder. This data is extracted from GPS or GLONASS onboard receivers and processed for ship navigation utilities or external solutions;
- d. To transmit augmented surveillance PVT and other positioning data from STC/STM stations to all oceangoing ships via GEO GNSS (navigation) satellite transponder, which will serve for enhanced collision avoidance; and
- e. To take less time in transmission, processing and delivery increased amount of information than the MRC network system itself does.

The modern MSC networks are designed to provide cheap, secure and fast communications between ocean-going ships and coastal utilities, as well as to connect all necessary systems in one operational RSAS network and to integrate GNSS-1 satellite data to implement a modern improved navigation monitoring and control. The integration of MSC and Internet technologies provides many solutions for the provision of new broadcasting and transmission services through multi-purpose spacecraft systems to SES onboard ship installations. With new requirements for enhanced satellite capacity, transmission and efficiency, the number of both GEO and Non-GEO communication spacecraft is steadily increasing. The global coverage needs the placement of multiple spacecraft in orbit to provide range of all areas of interest. For instance, the GEO satellite constellation requires at least 3 to 4 satellites in the network to provide adequate communication coverage [3, 7-10].

2.2. Maritime navigation subsystem (MNS)

The current (previous) maritime navigation subsystem and network is utilizing traditional ship VHF radio communication transceiver designed to transmit PVT, determination, positioning, distance, direction and ID information through CRS to STC/STM terminals using new VHF radio-automatic identification system (R-AIS) transceivers, which sample is shown in Figure 3 (a). In 2002, the IMO ratified the safe life at sea (SOLAS) convention as an obligation for all oceangoing ships over 300 GRT in international maritime traffic to deploy a Class A R-AIS transponder. In addition, the current maritime navigation system also utilizes onboard oceangoing ships additional equipment, such as radio direction finder (RDF) and automatic direction finder (ADF), both as onboard ships electronic navigation tools.

The GNSS-1 network consisting GPS and GLONASS satellites is realizing determination facilities for ships and other mobile systems at L1/L2/L5 frequencies, which are extracting PVT data via ships GPS or GLONASS receivers. In fact, the GNSS-1 networks and precise position are enhanced by local satellite augmentation system (LSAS) for seaports or RSAS infrastructures of the GPS or GLONASS solutions regionally. Then, the received GNSS-1 data from GPS or GLONASS satellites at same L1/L2/L5 frequencies by Ground Monitoring Stations (GMS) are forwarding via network coordination stations (NCS) to the ground control station (GCS) for processing, storing in files and displaying onto like radar screen for further usage.

The PVT data from GCS installation is transmitted via a GNSS (navigation) transponder aboard the GEO spacecraft and GES infrastructure to the SES terminals as an augmented GNSS-1 signal at L1 or L2 frequencies, which can be utilized for enhanced collision avoidance and ships guidance especially during extreme weather conditions. The maritime industry is also using the differential GPS (DGPS) network designed by the US Coast Guard office, which may be called the local VHF augmentation system (LVAS). Thus, the RSAS networks are integrated components of the GSAS networks to provide augmentation of GNSS-1 networks, while the MNS integrated in any RSAS network can transmit positioning data via voice or data, which sample is shown in Figure 4.

Therefore, the modern MNS network with onboard ships GPS or GLONASS receivers receive not-augmented GNSS data signals and simultaneously are getting augmented PVT data from GCS via CES terminals monitored by network control station (NCS). Thus, with the use of the GNSS data for oceangoing ships, there is a situation when its capabilities are not sufficient for the safety and ICAA demands for ships navigation across oceans, approach to coastal lines, anchorages and berths in ports. The RSAS network provides the safe sailing under the different navigation and weather situations and also when visibility is reduced. This network will be able to meet enhanced possibility for precise positioning and affordable solutions for transmission of the GNSS augmented information from the GCS and CES transceivers at the same GNSS frequency via GEO GNSS transponder to the SES terminals in all stages of the ship voyages [3, 4, 11, 12].

The safety of ships is the first requirement for deployment of AIS transceiver onboard of about 100,000 ships, which is shown in Figure 3 (a). Because it uses the VHF-band, its more convenient to call it as Radio-AIS (R-AIS), designed to provide unique ship positioning, tracking, course, speed and identification, all of which are indicated on a screen or an electronic chart display information system (ECDIS). In fact, the R-AIS onboard ship unit is dedicated to enable navigators on the bridge and provide to maritime authorities and seaports

determination, tracking, monitoring and management of vessel courses and positions. The R-AIS unit is composed by traditional VHF receiver and transmitter, GPS receiver and including navigation instruments, such as a ships gyro-compass, speed measuring devices, etc. In this sense, ships equipped with R-AIS transceivers sailing along shore waters may be monitored by R-AIS CRS terminals (base station) set up along coastal lines.

In general, R-AIS transponder is an automated system onboard ships that on a small screen displays other adjacent ships for enhanced collision avoidance. The R-AIS transponder is de facto radio transceiver equipment that operates in the maritime mobile VHF-band. Besides, the ship in question may also be seen on the screens of other ships in the near vicinity. However, if certain ship is not fitted with R-AIS or if it not switched on, there will be no possibility of exchanging position information and will be dangerous for safety in navigation. The R-AIS transponder onboard ship must always be switched on unless the ship's captain concludes that it must be turned off for the safety of the ship, crew and any other reason. The R-AIS unit can be also integrated with VHF data exchange system (VDES) software defined radio (SDR) for enhanced ships tracking solutions.

The new MSN network is integrating GPS and GLONASS systems as a components of the GNSS-1 network to provide secure not-augmented positioning data in real space and time. However, the GNSS-1 network integrated with GEO satellites in RSAS network will enable augmented GNSS (positioning) information, which is shown in Figure 3 (b). In the case when R-SAS terminal of the MNS infrastructure is out of coverage from shore monitoring system it can be used satellite-AIS (S-AIS), LRIT, SADS-B, SDL and new GST via spacecraft constellations. The S-AIS can operate via an increasing number of GEO and Non-GEO spacecraft constellations connecting vessels equipped with special S-AIS transceivers with ability to enlarge R-AIS range. The better application than LRIT is already stated GST system designed by author of this paper in 2000 [3, 13, 14].

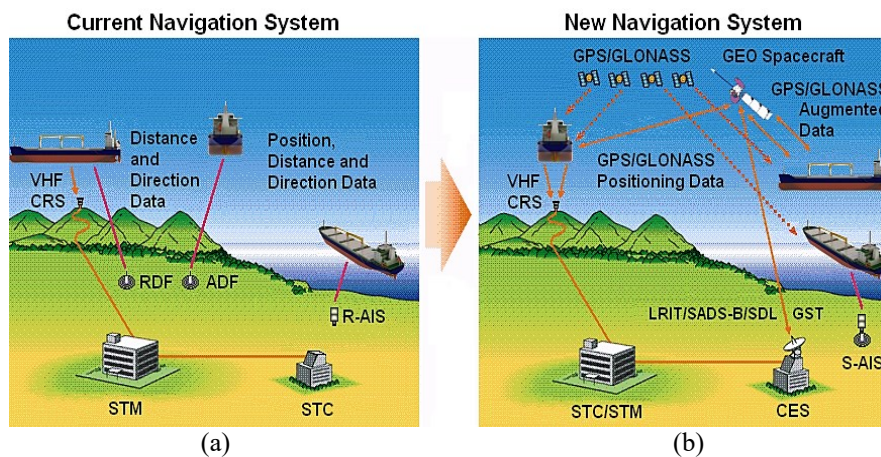


Figure 3. Maritime navigation subsystem for CNS/STM system; (a) current system and (b) new navigation system [3]

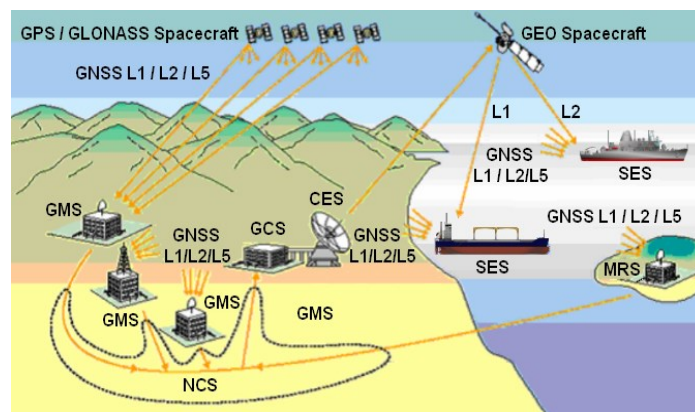


Figure 4. Modern MNS network [4]

2.3. Maritime surveillance subsystem (MSS)

The current maritime surveillance subsystem is provided by coastal ground surveillance radar (GSR), which is de facto the shore surveillance radars station deployed to provide surveillance of ships in coastal waters. In addition, MS service is also provided by traditional VHF voice/data positioning reporting system via VHF CRS and HF voice/data positioning report via HF CRS to the STC/STM terminals, which system is illustrated in Figure 5 (a). However, the new satellite MSS infrastructure is integration of the ships radar surveillance of the GSR shore stations, GPS and GLONASS GNSS-1 satellite constellations with Inmarsat or other GEO spacecraft networks. In such kind of scenario, the SES terminals onboard ships are receiving PVT and other data from GNSS-1 spacecraft and automatically or manually sends this information via SADS-B, SDL and GST through GEO satellites and CES terminals to collect navigation information to the STC/STM terminals, which network is depicted in Figure 5 (b). Furthermore, the new MSS subsystem can also build the back up GSR stations in the range of radar stations.

The modern MSS network for RSAS infrastructures can include GEO Inmarsat and as well as Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) MSC networks. The DVB-RCS satellite system is providing special onboard ships equipment introduced as a Very Small Aperture Terminals (VSAT) with C, Ku and Ka-band reflector dish. In fact, the DVB-RCS standards are the best solutions for deploying more reliable and effective MSC configurations as backbone to other conventional GEO satellite networks. The Inmarsat MSC network operates in such a way that all ships traveling across the ocean can receive their GNSS-1 positioning information from a non-augmented or augmented GPS or GLONASS shipborne receivers and transmit PVT navigation surveillance and other ship information via a GEO communication transponder and CES terminals to the ground STC/STM computing and display system similar to the radar screen, as is illustrated in Figure 6.

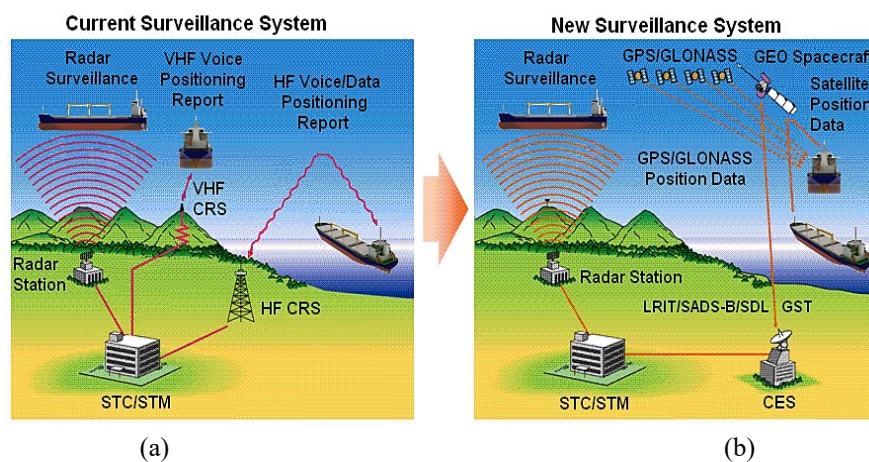


Figure 5. Maritime surveillance subsystem for CNS/STM system; (a) current surveillance system and (b) new surveillance system [3]

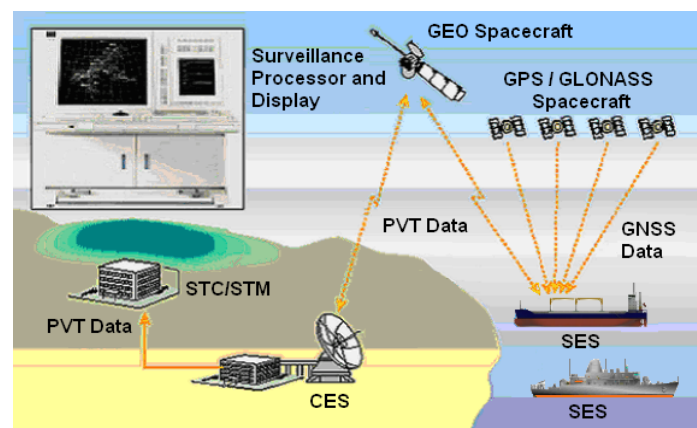


Figure 6. Modern MSS Network [4]

In contrast, the STC/STM terminals can forward positions from nearby vessels in a specific sea area via CES terminal, so the ship in question should receive this data to avoid eventual collisions. This solution is significant for vessels crossing the high seas during adverse weather conditions, reduced visibility caused by heavy fog and widespread clouds, when radars are unable to operate properly due to poor propagation effects. The positioning and other information obtained by the GNSS-1 (GPS or GLONASS) constellations are forwarded to the principal Surveillance Processor and Display (SPD) in STC/STM centres to be processed all positioning data and display on the screen like radar display. In the opposite direction, at the request forwarded by the captain from the ship, controllers at the SPD centre may transmit PTV augmented information, ID and positions of all vessel in particular areas via a GNSS (navigational) transponder onboard GEO satellites, for enhanced collision avoidance, especially during the night or extremely heavy fog and bad weather conditions, with strong wind, showers and thunderstorms. Therefore, the PVT data and other navigation reports may be sent from ships regularly and randomly by navigation officers. Otherwise, the ship's captain may request that these shore centre send him the positions of nearby ships or even receive such a type PVT and other data through the data report and polling system by command from the shore-based operational centre. In such a way, this system is using special data reporting and polling communication protocol to obtain PVT data and other information for enhanced collision avoidance and better ship guidance [3, 15-17].

3. SPECIAL EFFECTS OF THE MARITIME RSAS NETWORKS

The special effects of the maritime RSAS infrastructure are safety enhancements on short and long ranges, reduction of separation minima, flexible sailing profile planning and coastal movement guidance and control, which can be used for enhanced safety and secure CNS solutions, determination, positioning and surveillance of ships in navigation across oceans, sea channels, near by shorelines, approaching to the anchorages and in the port surface for traffic of ships and ground vehicles, such as truck and trains. These special effects of the MTAS satellite infrastructure are significant for current ship's communications, safety, separation, movement and control facilities at any stage of navigation, to provide observation of vessels during navigation, to allow flexible and economical travel to optimal courses, to improve surveillance, control, guidance and safety in coastal waters, anchorage approachings and in seaports areas [4, 18].

3.1. Safety enhancements at short and long ranges

A quite significant impact of the RSAS networks for enhanced CNS/STM solutions are to realize concept of the safety enhancement at short ranges (SESR) via CRS and GES terminals, which current or old radio communication network is depicted in Figure 7 (a) and new satellite network is shown in Figure 7 (b). At this point, present radio solution for short ranges between ships and CRS terminals is obtained by VHF voice or by digital selective call (DSC) VHF voice and data network and devices. In this way, the vessel's captain or navigating deck officer operating in SRS will have many difficulties to establish bridge-to-shore and shore-to-bridge voice radio transmissions with CRS terminals when the position of ship is in the overshadowed by chains of very high mountains in the shoreline sea waters. Otherwise, the role of a maritime pilot is very important in port operations, namely pilots help in maneuvering ship while arriving or departing a seaport.

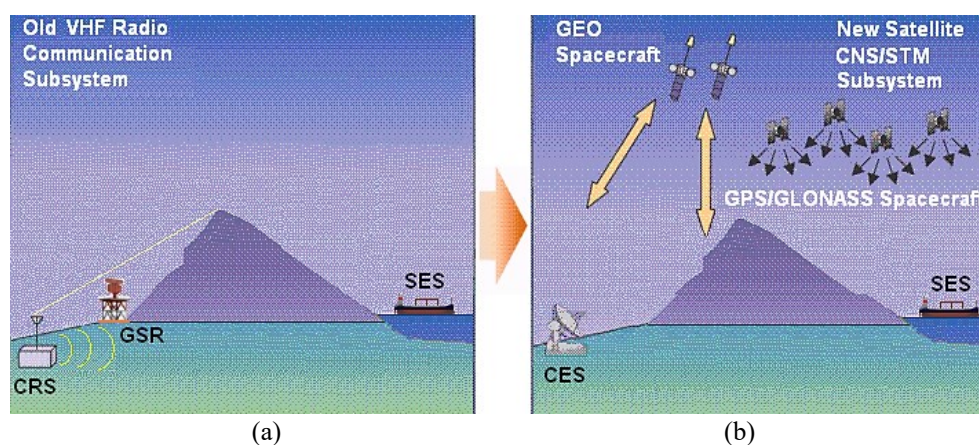


Figure 7. SESR Subsystem via CRS and GES terminals; (a) old VHF radio communication subsystem and (b) new satellite CNS/STM subsystem [5]

However, all ships operating in coastal waters or in the sea passages and in inside of harbours having problems to establish VHF radio connection, are able to provide satellite communication and navigation data transmissions even at short ranges and where communications and navigation cannot occur because of mountainous configuration. This possibility is significant for safe and secure sailing during extremely severe weather conditions and poor visibility in sea passages, anchorages and along cost to avoid disasters and collisions. The RSAS infrastructures and new satellite MSC CNS/STC systems are LOS solutions able to provide Safety Enhancement at Long Ranges (SELR) subsystem, which faded HF radio is shown in Figure 8 (a) and noise-free satellite system is shown in Figure 8 (b). At this point, numerous oceangoing vessels beyond the coverage of VHF radio communications can transmit via CES terminals their augmented or not augmented GNSS-1 position to STC/STM stations or will receive navigation and weather warnings for improved safety in navigation and collision avoidance [3, 19].

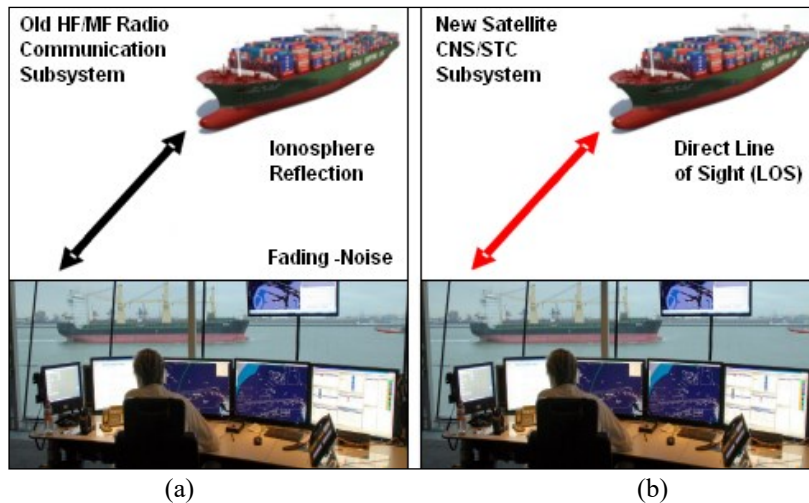


Figure 8. SELR subsystem; (a) old HF/MF radio communication (b) new satellite CNS/STC [5]

3.2. Reduction of separation minima (RSM)

The old or current reduction of separation minima (RSM) solution is controlled by VHF or HF conventional radio system and ground Radar Control Station (RCS) infrastructures, which allows large distances only between ships, as illustrated in Figure 9 (a). However, the new CNS/STC system provides improved monitoring and distances of many ships in the same sea passages, which allows the minimum secure separations and enhanced collision avoidance. The new CNS/STC network provides twice the capacity of the RSM system for vessels with important safety and security improvements, which scenario is depicted in Figure 9 (b). In this way, significant RSM system will be available for all kind of oceangoing vessels with increased possibilities for implementation of the new RSAS techniques in the CNS system worldwide [3, 20].

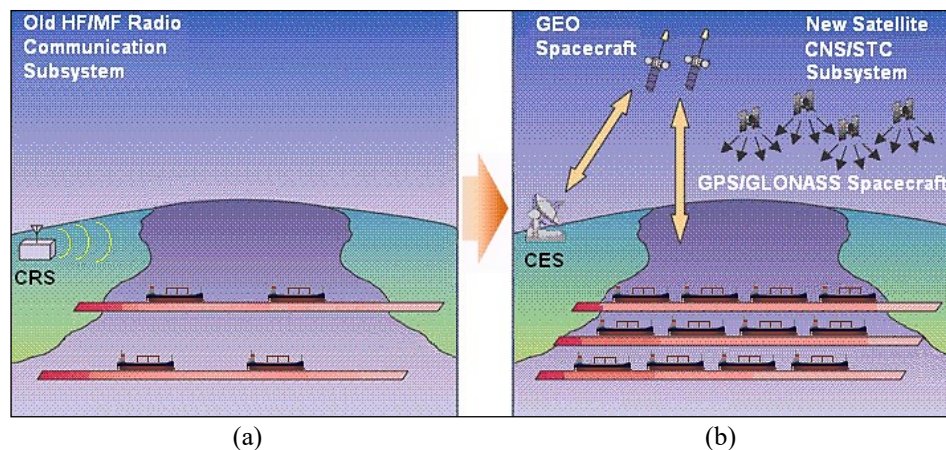


Figure 9. RSM subsystem (a) Old HF/MF radio communication (b) new satellite CNS/STC [5]

3.3. Flexible sailing profile planning (FSPP)

The further very important solution for significant improvement of ship navigation in high sea routes is flexible sailing profile planning (FSPP) old or current and optimal or shortest ship routes. In Figure 10 (a) is shown the current subsystem that is using fixed courses of loxodrome, orthodrome, and integrated positioning combined navigation by navigation aids. The fixed courses are monitored by the different ship's onboard determination and positioning tools only, which are a complex and not the shortest possible course of vessels from departure to arrival at the destination seaport. On the other hand, the ship's captain can choose the shortest or optimal routes that are providing precise course of vessels with almost like a straight line, which scenario is depicted in Figure 10 (b).

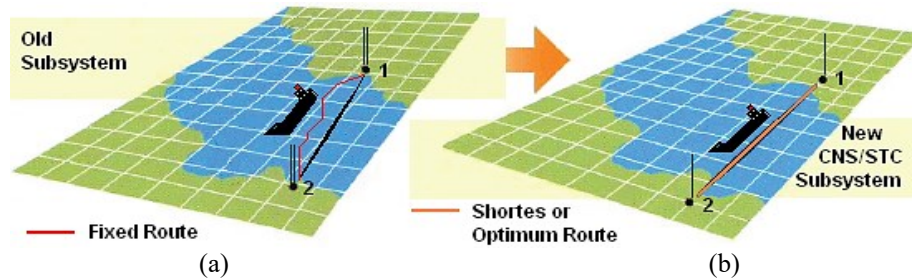


Figure 10. FSPP Subsystem using (a) fixed route (b) shortest or optimum route [5]

This is why the new FSPP solution with shortest routes are allowing to navigation officer to select the shortest or optimal courses between two harbours with few sub-points. Thanks to the new RSAS infrastructure associated with modern CNS/STC systems, FSPP should be used on the navigating bridge for more economical and effective voyages. In such a way, vessel's engines will consume less fuel by choosing the shortest sailing route of new CNS/STC system than by choosing the fixed routes of the present composed course [3, 4, 21, 22].

4. COASTAL MOVEMENT GUIDANCE AND CONTROL (CMGC)

The modern RSAS infrastructure can be deployed as a new designed coastal movement guidance and control (CMGC) solution combined with CNS as a part of any RSAS configuration for movement control in and around harbour. In fact, this is a specific harbour safety and monitoring solution that allows the traffic operator in seaport control tower to collect all maneuvering, movement and positioning information from all vessels and land vehicles, trucks and trains, to compute this data and indicate them on the surveillance control display like radar screen. The traffic controller in the harbour control tower will be able visually to observe and control into surveillance control display the position and courses of all ships in nearby sailing area, which can be monitored, managed and hand over to traffic participants in any real space and time. The RSAS vessel traffic controllers conduct basic control of all mobile movements, organize traffic management, guide and monitor of the vessels movement along the coast, in narrow channels and fjord lanes, approaching areas to anchorages and seaports, arrange movement of ships in harbours including land vehicles in and around the seaport's coastal surrounding, even during very reduced visibility and bad weather situation when ships are approaching the harbour.

The harbour's traffic controller is providing instructions to the ship's masters, deck officers and pilots with a call to the command control screen in the control tower that provides all information about the position of vessels in the vicinity that have been detected by satellites and ground sensors. The surveillance screen in a control tower also displays and may report the position data of arriving and outgoing vessels and all auxiliary land vehicles, such as road and rail, moving towards seaport or circulate at its surface. The positions of ships and other mobiles is determined utilizing information messages from GNSS-1 (GPS and GLONASS) satellites and GEO spacecraft constellations. The seaport comptroller provides to ship masters and pilots the proper course of their ship with increased security, even during extremely weather conditions and reduced visibility, or gives necessary advices on safe courses and information on routes and separation from other ships in close vicinity.

The following segments of CMGC network are shown in Figure 11:

- GPS or GLONASS GNSS spacecraft determines the correct position of ships or harbour vehicles, which can be indicated at displays of their onboard receivers;
- GEO MSC spacecraft constellations are caring onboard both communication and GNSS (navigation) transponders and except that they are complementing the GPS or GLONASS spacecraft in performing

- GNSS-like tasks. The GEO satellites also have the ability to transmit data between the vessels or land vehicles and ground-based structures, pinpointing the exact position of all mobile movements.
- Control tower is a traffic monitoring centre that provide monitoring and control of the sea passages, accessing areas around the coastal lines and in the seaport waters and surface. The position of all ships and land vehicle in seaports is indicated on the monitoring display of the seaport control tower. Based on the processed data, the tower controller remotely manage, directs and navigates seagoing ships and off-road vehicles inside of harbours.
 - Light guidance system (LGS) is operated by a traffic operator in a control tower that indicates a green or red light for guidance on whether or not the ship should proceed by the pilot in port.
 - Radar Control Station (RCS) is a component of the old solution for MTC of vessels navigation in the sea passages, approaching to anchorages, in port and around the port's coastal environment.
 - Very high frequency (VHF) is Coast Radio Station (CRS) is a main component of RCS and VHF or Digital Selective Call (DSC) VHF-band transmission network.
 - Ground earth station (GES) is a principal component of the transmission system between GES infrastructure and land telecommunication systems via GEO spacecraft networks.
 - Pilot service is small boat or helicopter carrying the special trained man known as a Pilot, whose task is to navigates vessels into or out of harbors, channels, bays, rivers or lakes.
 - Bridge instruments onboard all ships are used to measure and indicate speed, course, position, depth and distance from a set point, [3, 4, 23-25].

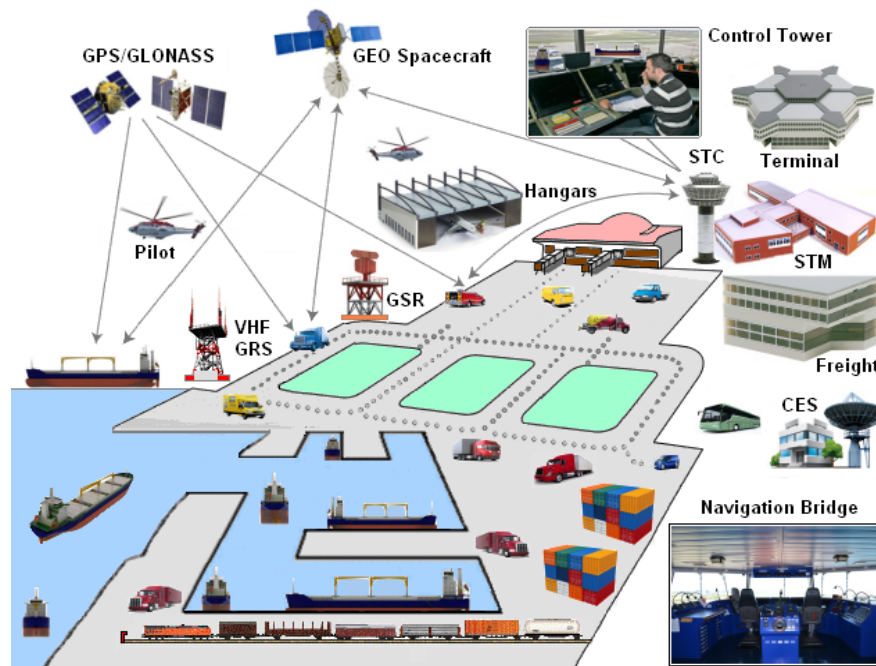


Figure 11. CMGC Subsystem [6]

5. CONCLUSION

The RSAS were implemented to provide more advanced solutions for global space CNS systems, enhanced security, control and management of oceangoing ships, freight of goods, saving passengers lives in eventual distress situation and SAR service according to IMO and SOLAS regulations and recommendations. The modern space CNS system for maritime applications utilizing GEO satellite constellations with communication and navigation transponders providing STC/STM service is designed to assist in the safe and efficient navigation in all stages of voyages. The potential benefits in shipping transport will assist STC terminals to solve increased vessels traffic, to enhance safety and reduce the required installations on the coast. The main goal of RSAS networks are is to improve safety and security for maritime applications, especially in the unfriendly coastal waters and in seaports without ground infrastructures and surveillance radars. The final goal of essential RSAS networks will boost the transportation industry, reduce consumption of fuel, provide more cost effective trips and increase economic growth in certain region.

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