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Architecture of the global navigation satellite system for maritime applications

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ABSTRACT

This paper introduces architecture of the global navigation satellite system (GNSS) networks in the function of the maritime space communications, navigation and surveillance (CNS) for enhanced navigation and positioning of vessels deploying passive, active and hybrid global determination satellite systems (GDSS) networks. These GNSS networks have to enhance safety and control oceangoing ships in navigation across the ocean and inland waters, to improve logistics and freight of goods, security of crew and passengers onboard ships. The maritime GNSS networks integrated with geostationary earth orbit (GEO) satellite constellations are providing important global satellite augmentation systems (GSAS) architecture, which is established by two first generations known GNSS as GNSS-1 infrastructures. The GNSS-1 network is the composition of two subnets such as the US global position system (GPS) and Russian global satellite navigation system (GLONASS). Both GNSS-1 networks play a significant contribution in very precise timing, tracking, guidance, determination and navigation of the oceangoing ships. At this point, both GNSS-1 networks, GPS and GLONASS, are used in maritime and many other mobile and fixed applications to provide enhanced accuracy and high integrity monitoring usable for positioning of the oceangoing ships. To provide improvements of GNSS-1 network it will be necessary to carry out their augmentation within several regional satellite augmentation systems (RSAS) as integration parts of GSAS infrastructures.

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1. INTRODUCTION

The present configurations of the GNSS networks consist two basic solutions for position, velocity and time (PVT) and other determination data provided by GPS of the US military forces and by GLONASS of the Russian (former-Soviet Union) military forces. Both networks of GNSS-1 or first generation satellite navigation infrastructure, that provide accurate positions of about 30 meters used onboard ships as GPS or GLONASS receivers (Rx), de facto suffer from some technical weaknesses and because of these anomalies they cannot be used as the only means of navigation for oceangoing vessels and all moving objects at sea.

Technically, both independently used GNSS-1 networks are quite unable to meet the extremely high integrity, continuity, accuracy and availability (ICAA) requirements, especially for ship traffic control (STC) and enhanced marine CNS solutions, so they are not complete and adequate for certain critical sailing of ships on the high seas and maneuvering in seaports. In order to ensure significant improvements over the GNSS-1 networks, it will be necessary provide their augmentation over the GSAS and their RSAS integration portions.

Because these two GNSS-1 networks are designed to fix up positioning data of determination and velocity via GNSS-1 receivers onboard ship’s bridges, so only master mariners onboard oceangoing vessels have their actual position and speed, but adjacent ships and operators in STC terminals cannot get in all cases their positioning information without the assistance of modern CNS systems. In addition to GPS or GLONASS accuracy, it will not be possible to obtain a valuable traffic control of ships in any emergency or dangerous situations without a modern CNS systems. In such a way, these two GNSS infrastructures were primarily designed specifically for military applications and are recently also implemented for maritime and other commercial transportation applications around the world, however, many governments and world organizations will never want to be dependent on or trust in the GNSS service provided and controlled by only two countries.

That's why they have been lately projected and developed augmented GPS and GLONASS (GNSS-1) networks of the RSAS or satellite based augmentation system (SBAS) infrastructures to enhance the shortcomings of the existing two stated GNSS-1 military solutions and to provide high-operational ICAA values for current civilian requirements in maritime transportation. The current operational RSAS networks are the european geostationary navigation overlay system (EGNOS), the Japanese MTSAT satellite enhancement system (MSAS) and the american wide area extension system (WAAS), which are capable of providing CNS information from all ships including other mobiles, to the traffic control centres (TCC) or ship traffic control (STC) via the GEO spacecraft.

The above RSAS networks are integrated interoperable and compatible GSAS components for augmentation of the GPS and GLONASS networks of GNSS-1 architecture, include the new designed EU Galileo and Chinese BeiDou (compass) as GNSS-2 architecture. Besides, the GSAS networks also integrate the Inmarsat civil navigation satellite system (CNSO), Indian GNSS and GEOS augmented navigation (GAGAN), Chinese satellite navigation augmentation system (SNAS) and Russian system of differential correction and monitoring (SDCM). In the meantime is projected African satellite augmentation system (ASAS), which expects the attention of interested investors, sponsors and prime contractors. In addition, two more projects of the RSAS networks need to be completed and to cover all areas of Australia and South America for establishment of the GSAS infrastructure worldwide, which infrastructure is depicted in Figure 1.

All RSAS networks are designed in accordance with world standards, they are interoperable because do not overlap with one another and compatible when using a conventional GNSS receiver that provides the same amount of support and achievements whether located in the WAAS or MSAS and any other RSAS footprint areas. Besides to their utilization in the maritime industry, RSAS networks are important for service where continuity, accuracy and other components are critical. They are mostly needed where lives of seamen are concerned or when commercial or legal conditions are required. For example, the RSAS infrastructures enable the enhancement and expansion of applications for GPS or GLONASS solutions for fleet management in all transportation s ystems, precision mechanization in agriculture, positioning of the offshore platforms, for scientific explorations in the aerospace and naval industries [1-5].

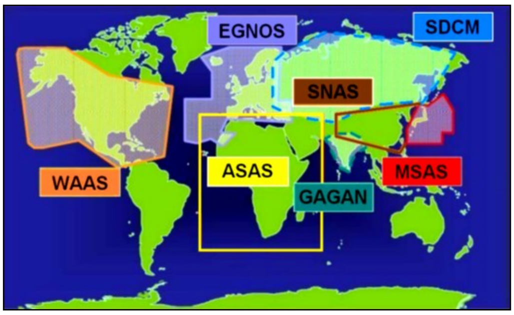

Figure 1. GSAS Network Configuration [4]

2. DEVELOPMENT OF GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

The GPS and GLONASS space segment is composed of 24 GNSS1 satellites each, while their ground segment is composed of Ground Earth Stations (GES) and users known as Ship Earth Stations (SES), which scenario is shown in Figure 2. The present GNSS-1 infrastructure has been developed as complete operational in 2009/10, which represent satellite positioning systems important for obtaining significant PVT data in multimodal transport systems such as ocean-going vessels, road vehicles, railways and airplanes. Thus, the GNSS-1 infrastructure is composed by GPS or GLONASS spacecraft, ground stations, onboard ships GNSS receivers and a control system for monitoring the global GNSS signals according to the operational standards previously established. The new GNSS infrastructure will improve, upgrade or modify current systems that have shortcomings in regard to availability, integrity, monitoring and system life expectancy.

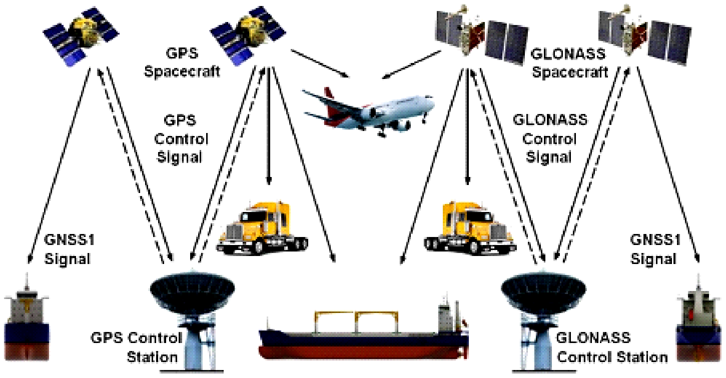

Figure 2. Existing GNSS-1 Networks [4]

The maritime CNS service complies with the rules and recommendations of the international maritime organization (IMO) in provision concerning mandatory for installations of radionavigation equipment onboard oceangoing ships including a world wide radionavigation system (WWRNS). Thus, all the basic processes and requirements for the implementation of GNSS must comply with the IMO WWRNS regulations. There are modern and significant processes for the implementation of radio communications, navigation and information systems, which should be included for technological transfer and innovations for use in maritime industry. The GNSS networks for augmentation of the GPS or GLONASS spacecraft are designed to improve PVT performance for maritime and other transportation systems. Besides, mobile devices can be performed to utilize integrated sensors for added robustness in the event of downtime or satellite signals are blocked during poor signal propagation. Some mobile applications, such as shipborne and airborne radionavigation systems, require much higher accuracy than GPS or GLONASS alone. The modern augmented GNSS-1 infrastructure of the GPS and GLONASS networks have been integrated into RSAS along with GEO to obtain necessary ICAA requirements for all stages of vessels sailing across oceans, coastal navigation and approaching to the anchorages.

Meanwhile, the RSAS interoperability working group (IWG) is a concept for RSAS (SBAS) system operators to agree mutually and implement the overall design, integration and compatibility of all future RSAS networks within the GSAS infrastructure worldwide. Moreover, the IWG Concept enables coordinated implementation of common shipborne or airborne solutions developed for proper transition from one RSAS region to another, which must be compatible across the GSAS network globally. All RSAS infrastructures will provide improved ships traffic control, management and safety, which service is available without charges. In such a way, RSAS network are providing performance based navigation (PBN) system to improve effectiveness, system redundancy and quality of the ships positioning service, to minimize environmental effects and to provide the lowest cost for required navigation performance (RNP).

Meanwhile, in unreal solutions that are beyond real time, the differential corrections (DC) of GNSS signals may be memorized together with position of different users and utilized after the receiving and processing period. Otherwise, this unreal time application is practically implemented in the surveying process. The local area differential system are usually referred as reference station (RS) terminals located within line-of-sight (LOS) in relation to all users. At that point, as the range between the RS and the user increases, some distance errors appears as decorrelated. This problem can be solved by deploying a specific network with a specified number of RS terminals known as ground monitoring stations (GMS) spread over a significant area, such as a continent, region, or even a large country, and provide transmission of DC signals through GEO satellites. However, it is very important to conclude that LEO spacecraft cannot be used to realize this type of service, because robust GNSS transponders cannot be installed in the reduced payloads. During the further process, the RS terminals forwards the collected data to any operational master control stations (MCS) or ground control stations (GCS), where the obtained DC values are computed, executed and the integrity of the satellite signal is verified. Finally, the MCS terminal then transmits the corrections and integrity data via GEO spacecraft uplink and GES or Gateway downlink to the user terminals [2, 4, 6-8].

3. GLOBAL DETERMINATION SATELLITE SYSTEMS (GDSS)

The determination of mobile positions via GNSS network was used for the long time to provide reliable solutions for very precise navigation requirements, especially for the oceangoing vessels in maritime satellite system and longhaul flight aircraft in aeronautical satellite system. The recent development of the land mobile satellite system for road and rail vehicles has also created requirements for development similar land-based mobile user identification and monitoring services. The mobile determination operators provide global and cost-effective location of position facilitating all these users connected to a large and growing customer database [6, 9].

3.1. Pasive GDSS

The GPS or GLONASS receivers onboard ships or other mobile stations receive continuous data sent over a passive GNSS networks which scenario for all mobile systems is illustrated in Figure 3. In this way, mobile users calculate their own position by extracting this data from the GNSS receiver, so for that reason all mobile users must have onboard installed GNSS receiver. More exactly, in such special category of mobiles using GNSS receivers can be included oceangoing vessels, aircraft and all types of land vehicles. Passive GNSS systems have been successfully used for a long time and have been active for a long time and usually have the following characteristics:

a. Two-dimensional correction requires three visible spacecraft, while three-dimensional correction requires four visible spacecraft;
b. Each user can realize his position independently and without alerting the other participants about his presence. The amount of users present and the frequency with which they can get all the updates are not limited by the system power or bandwidth. However, in conclusion, passive GDSS solutions are more cost-effective, especially when the number of users is increased and when there is a need to update their positions. Thus, the cost of the system is independent of the number of users and the amount of usage.
c. The cost of the equipment is low because users do not need transmitters, although they may use communication equipment for other solutions. Otherwise, they can be also easily used in combination with other solutions such as GPS, GLONASS, Loran-C and/or even in mutual conjunction.
d. Space infrastructure and in particular ground configuration is not complex, in part because users have a responsibility for computing positioning data [2, 4, 6, 10, 11].

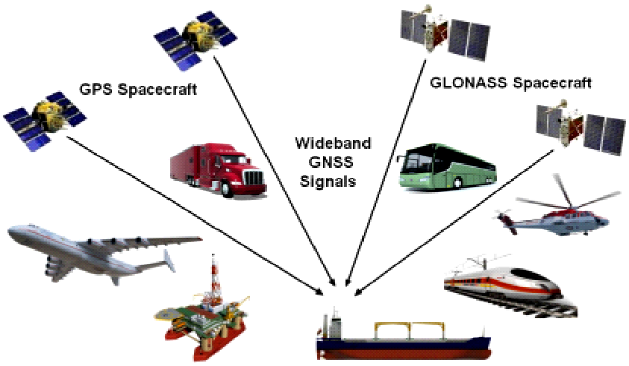

Figure 3. Passive satellite determination [5]

3.2. Active GDSS

In active GNSS networks, mobile terminals send navigation data via spacecraft, and terrestrial operators in the main computation center receive this data to determine the position of mobile terminals. The determination data can then be returned to the mobile terminal or any different positions, as shown in Figure 4. The position of the mobile terminal can only be computed when it sends the required signal. Usually, the signal is conducted via spacecraft to the computation centre, where the position is then determined. As the position of the mobile terminals in the computation centre is known, the active system can be applied for mobile surveillance, mainly for ships positioning, ground and air traffic control. Thus, surveillance is the main task of traffic controllers, who need to determine location of ships, airplanes and land road and rail vehicles. For instance, a central facilities for cargo onboard vessels could track specific cargo, such as dangerous or perishable cargo and vessel tracking system.

The features of the active GNSS network are as follows:

a. Two-dimensional system for determination of mobile positions needs minimum two visible GNSS spacecraft, while three-dimensional applies three;
b. The mobile terminals should be able to communicate with the facility centre. In particular, this centre does need the computing capacity, since the position computation are centrally managed;
c. Active radio positioning facilities are able to arrange determination data about the position of one mobile terminall relative to another, which is significant for shipborne and airborne solutions; and
d. The central facility is able to enhance position acuracy of mobile terminals by utilization of location data from reference mobile stations [2, 4, 6, 12].

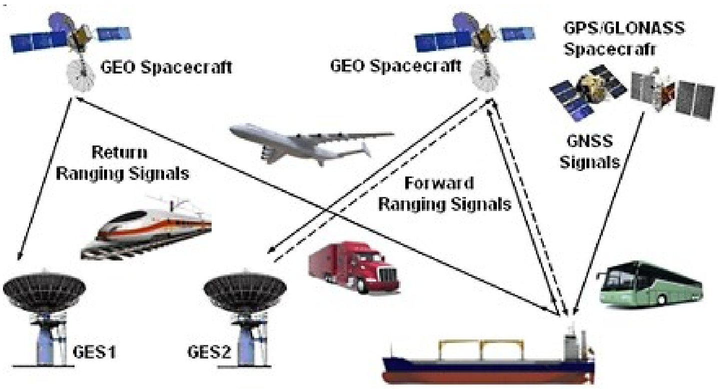

Figure 4. Active satellite determination [5]

3.3. Hybrid GDSS

In hybrid GNSS networks, the mobile terminals detect ranging signals in their receiver via the number of spacecraft and position is computed by calculating the time or phase differences of the signals. At this point, ranging data can be determined in position when two or more GNSS spacecraft are in LOS to the mobile terminals, which scenario for maritime and other mobile CNS applications is depicted in Figure 5. In such a way, the hybrid mobile positioning system is similar to applications that operate via GPS or GLONASS and Loran-C determination networks. The determination signals are then transmitted via the spacecraft to a central facility station, where the position of the mobiles is calculated and presented on the display such as a radar screen, which system is usually designed for use via certain GEO or Non-GEO spacecraft.

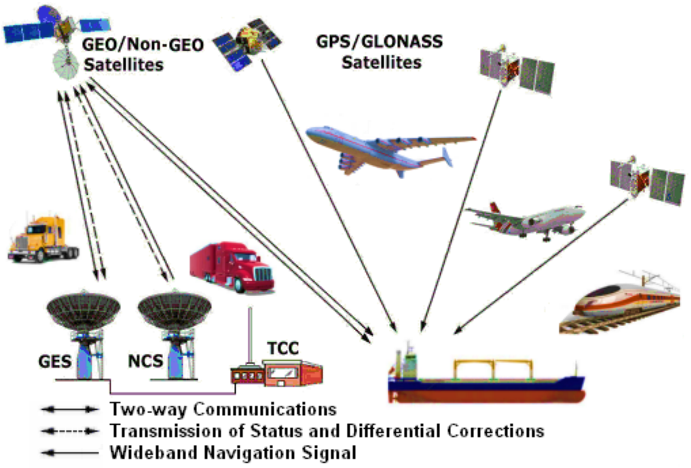

Figure 5. Hybrid Satellite Determination [5]

The hybrid GNSS networks enable to ships and other mobiles via central facilities to compute their positions. In maritime navigation, operators must carry out all computing of positions onboard vessels, where daily performances of the CNS, monitoring and tracking are required. In reality, the hybrid GNSS networks have most of the benefits over active networks, and they also offer interoperability with GPS, GLONASS and any new civilian GNSS networks. Therefore, features of the GDSS hybrid networks, similar to the new developed RSAS networks, include the effectiveness of radio frequency spectrum, high precision positioning, uniformity effects on pseudo-range tracking errors, integrity of the ephemeris and clock data in the broadcast navigation messages, very simple mobile equipment, flexible control and monitoring, etc [2, 4, 6, 13, 14].

4. MARITIME GNSS APPLICATIONS

The above mentioned RSAS networks provide global converge with main propose to improve operational GPS and GLONASS PVT performance systems in shipping industry. Therefore, the shipborne GNSS solutions require far greater accuracy and reliability of the CNS than current GPS and GLONASS space infrastructure can provide. Positioning precision can be enhanced by eliminating correlated errors among two or more GPS or GLONASS onboard Rx terminals that perform range measurements from the same spacecraft. Thus, these ships GNSS Rx equipment is de facto a reference receiver (RR) surveyed in and which geographical position is accurately known. In this way, one way of obtaining usual debugging is to distinguish between the position of the RR station under test and its instrumentally extracted position at a separate time periods. The variations in calculated position are determined as a measured time errors referred as the DC value, which data can be transmitted via the GEO satellite link to the GES terminals. In such a way, the GPS or GLONASS onboard ship augmented Rx can eliminate errors from detected signals.

In another way, in GNSS non-real time positioning, DC measures can be memorized together with the positioning data of different users and will be utilized after a period of data collection and storage, which scenario is commonly used in surveying systems. The RR or ground monitoring station (GMS) for the maritime applications will deploy a solution named as a local area differential, which is similar to the RSAS or the US shipborne DGPS networks. At that point, if the distance among the user and the GMS increases, some range errors are occurred as decorrelated. This anomaly can be solved by establishment of a special ground infrastructure with numbers of the GMS reference stations across a significant geographical areas, such as a continent or large countries, and broadcast differential corrections (DC) through the GEO satellite networks. Therefore, the new projected ASAS as RSAS network will provide coverage over entire African and the Middle East.

Thus, all GMS terminals associated to the terrestrial telecommunications networks (TTN) are performing transmissions of associated data in the direction of an accessible ground control stations (GCS), which performs DC and controls the integrity of the spacecraft. Besides, the GCS terminal transmits correction and integrity data to the ground Gateway or GES terminal as an uplink to the GEO spacecraft. This differential technique is called the wide area differential system, which implements the GNSS network named as wide augmentation area (WAA). Another infrastructure for mobile applications called as local augmentation area (LAA) or local satellite augmentation system (LSAS) is a modern system of a local area differential. The LAA network is a new project for navigation of ships in coastal waters, approaching to anchorages and for harbours. The WAA is an implementation of wide area CNS systems for all mobile solutions including maritime, such as Inmarsat CNSO and other RSAS infrastructures established in the Northern Hemisphere.

Operational RSAS networks are components of the GSAS worldwide infrastructure that is integrating networks of the GNSS-1 (GPS and GLONASS) and GNSS-2 (BeiDou and Galileo architectures, including the CNSO GNSS network that offers this service through Inmarsat 4/5 generation and Astra satellites. The author of this article has suggested GSAS as a new and more appropriate name than nomenclature satellite-based Augmentation System (SBAS) proposed by ICAO, which should be accepted as a more appropriate name under the new CNS systems. These RSAS networks in integration with Inmarsat CNSO are interoperable, compatible and each contains a GNSS-1 (GPS or GLONASS) network of determination terminals and own or leased GEO communication spacecraft [4, 6, 15, 16].

4.1. RSAS system configuration

The RSAS network has been designed and implemented as a primary means of satellite CNS for maritime transportation, such as ocean crossings, coastal and inland sea navigation, channels and passageways, approaches to anchorages, inside of ports, and for control of road and rails vehicles inside of harbours. In this regard, it will also serve to control the flight routes of aircraft in the corridors over continents and oceans, to control approaching to airports and manage movement of all airplanes and land vehicles on the airport surfaces. It was planned to performs the following specialized services:

a. Broadcasting of integrity and health data from each GNSS-1 (GPS or GLONASS) spacecraft in the real time to anounce all vessels or other mobile terminals do not use faulty spacecraft for positioning, which system is proposed as the GNSS integrity channel (GIC);
b. Uninterrupted broacasting of ranging signals as a part of the GIC service is dediacatd to complement GNSS infrastructure, and thus, to mprove GNSS-1 (GPS or GLONASS) signal availability. Improved signal availability also refers to the enhancement of the receiver autonomous integrity monitoring (RAIM) availability, which is known as ranging GIC (RGIC); and
c. Broadcasting of GNSS-1 (GPS or GLONASS) wide area DC values, as a complement to the GIC and RGIC services, improve the accuracy of civilian GPS and GLONASS signals. This function is called the wide area differential GNSS (WADGNSS).

The Inmarsat, Astra and other satellites are dedicated as a space segment for RSAS network shown in Figure 6, which is essential for the future CNS system such as: all ships and other mobile terminals (3) receive positioning signals (1) from GNSS-1 (GPS or GLONASS) spacecraft. As stated, very soon will be operational GNSS-2 (BeiDou and Galileo) positioning spacecraft (2).

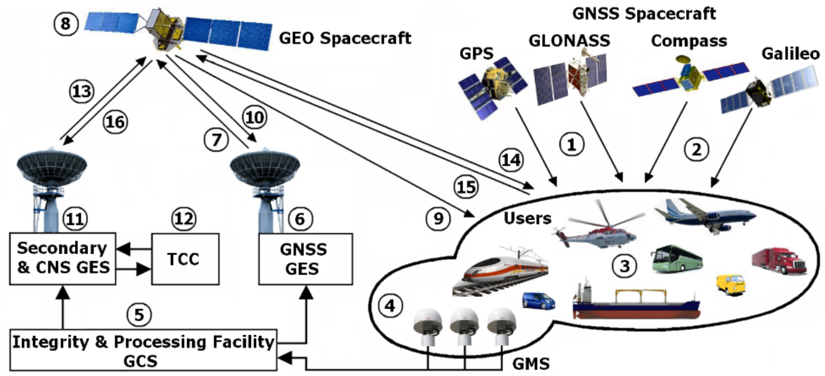

Figure 6. ASAS network configuration [6]

The reference GMS terminals are also receiving positioning signals of integrity monitoring (4) managed by specialized governmental agencies in many countries within RSAS footprint, including ASAS network that covers African continent and Middle East region. The positioning data is then forwarded to a regional integrity and processing facility of GCS (5), where data is processed to provide integrity and WADGNSS correction messages and distributed to the primary GNSS GES terminal (6). At the GES terminals, the positioning data is synchronized very precisely at the reference time and is modulated by GIC message data and WADGNSS corrections. The positioning data are broadcasted to the spacecraft at the C-band uplink (7) via GNSS transponder located onboard GEO Inmarsat and Astra satellite (8), the augmented data is frequency-translated to the mobile terminals on L1 and new L5-band (9) and to the C-band (10) used for maintaining the positioning data timing loop. The timing of the data is done in a very precise manner in order that the data will appear as though it was generated onboard the GEO spacecraft as a GNSS ranging signal. The secondary GNSS GES terminal can be deployed in communication CNS GES facilities (11), as a backup station in the event of a failure on the Primary GNSS GES terminal. The TCC ground terminals (12) can send a request to all mobile terminals for providing CNS information by voice or data transfer, including new voice, data and video over IP (VDVoIP) at C-band uplink (13) via communication transponder carried onboard Inmarsat or Astra spacecraft and at C-band downlink (14) to mobile terminals (3). All mobile terminals can broadcast augmented CNS data at L-band uplink (15) via the same GEO satellite and L-band downlink (16). The TCC terminals are processing CNS data received from mobile terminals by host and in the real time precisely displaying their actual positions on the surveillance screen [13]. Thus, RSAS or ASAS networks in particular can be used as a main means of positioning for all mobile applications [6].

The RSAS space segment is usually an integrated constellation of 24 operational GPS and 24 GLONASS spacecraft, including 1 Inmarsat and 2 Astra GEO spacecraft. Otherwise, GEO satellites downstream navigation data to users on GPS or GLONASS (GNSS) L1 RF, with a modulation equal to that used by GNSS network. The message in the positioning data, when processed by RSAS RX, allows GEO spacecraft to be used as additional GNSS-like spacecraft, thereby improving the availability of spacecraft constellation. At this point, the RSAS signal is similar to the GNSS signals that appear from the Gold Code family of 1023 possible codes (19 signals from PRN 120-138) [2, 4, 17, 18, 19].

4.2. Maitime transportation augmentation system (MTAS)

The GNSS transponders onboard GEO spacecraft are main components of the whole system. In fact, it transmits navigation data to mobile terminals in the same manner as GPS or GLONASS spacecraft to improve the ICAA positioning values. The received GNSS data from all mobile terminals, contain its status information, correction factors of the GPS or GLONASS spacecraft and for few tens of meters significantly enhance the reliability and accuracy of the current GNSS network. The accuracy of the augmented GPS and GLONASS networks will be only a few meters, allowing ships and vehicles to be controlled with the GEO satellite only, without ground-based radars or radio beacons infrastructures. In order to complement the GNSS (GPS or GLONASS) channels, communication links allow two-way (interactive) transmission between ship earth station (SES and GES terminals. The SES terminal sends positioning data to the port authorities, TTC terminal and the competent shipowners or port authorities.

This procedure allows the movement of the ship to be better controlled and to improve safety at sea and operational efficiency. The GEO spacecraft will transmit flexible and secure routing data to oceangoing ships terminals through the shipping coastal centers, which procedure will decrease the fuel consumption, reduce navigation time and improving safety and security systems. The CNS/MTAS satellite mission is divided into three maritime CNS systems, such as communication, navigation and surveillance. In the general sense, the MTAS system consists of space and ground segments [4, 20].

4.3. Space segment

The space segment for MTAS configuration and mission, as part of the GSAS infrastructure, may be the same newly designed GEO and/or chartered Inmarsat, Japan's MTSAT, European Astra, or any existing GEO satellites with sufficient space for a GNSS transponder within the satellite payload. The GNSS payload in the GEO spacecraft can provide a global and point-of-cover position at some 36,000 km above the equator. The MTAS spacecraft may also have an innovative payload for the maritime mobile satellite communication service, which will be similar to the Inmarsat mobile satellite communication system (MSC). The main component of the satellite transponder is an intermediate frequency (IF) processor that splits all incoming links and retransmit them to the corresponding two-way beams: forward (ground-to-ship) and return (ship-to-ground). In effect, the global satellite beam is covering 1/3 of the Earth surface between 75o North and South latitude. Otherwise, spot satellite beam coverage typically consists of 6 spot beams over certain regions, including offshore links, to meet the requirements of increased maritime transport operations and greater safety and security.

The features of the GNSS data are in accordance with ICAO Annex 10 (SARP), IMO and Inmarsat SDM and are in accordance with radio regulations and ITU-R recommendations. This type of spacecraft has two of the following types of satellite links associated to the maritime ship earth stations (SES) and ground earth stations (GES):

a. Forward GES to satellite direction

The GES terminals are situated all over the certain area, which transmissions are receiving by L, Ku or Ka-band shipborne antenna. Because it is using very high radio frequency (RF), the reflector size is quite small, 500 mm for the Ku-band, 450 mm for the Ka-band and double for the L-band. The shipborne antenna reflector is movable by the ships tracking motors automatically correcting azimuth and elevation angles. The focusing motors of the shipborne antenna are connected to the ship gyrocompass, so it can work with the transponder in communication spacecraft in any of the possible ship positions in the four GEO overlays, which scenario is shown in Figure 7. The GES is using C-band feed links and the SES is using L-band service links with onboard a larger antenna size than the Ku and Ka-band antennas. The SES standards use the new broadband technique and are capable of providing broadcast, multimedia and Internet services for VDVoIP and IPTV. The receiving signals are then amplified, converted to IF, filtered and passed to the IF processor, where they are then converted and transmitted to the SES terminal. By the way, the author of this article proposed this broadband solution in 2000 as maritime broadband, seven years before Inmarsat offered and promoted its FleetBroadband.

b. Return satellite to GES direction

The L-band signal received from approaching SES are processed in the same way and retransmitted to GES terminal via Ku and Ka-band GES antennas, although the GES system can also employ Inmarsat C-band transmitter and antenna. The output power of the Ku and Ka-band SES transmitters is only 2V thanks to the high gain satellite dish. It is also possible to provide station-to-station links in either the Ku or Ka-band range so that stations operating at different spots can communicate with each other. The GNSS channel is also routed to the GES terminal in two bands for calibration purposes [2, 4, 6, 21, 22].

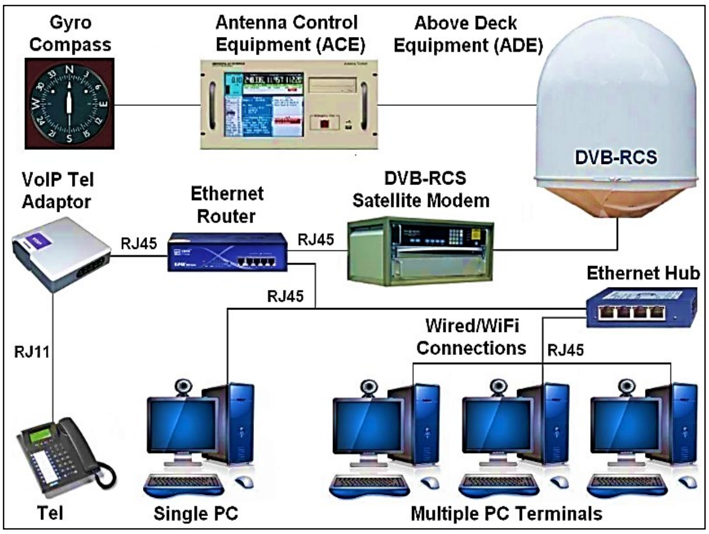

Figure 7. SES or Shipborne DVB-RCS Terminal [6]

4.4. Ground segment

The MTAS ground segment is constructed from multiple GES and ground control terminals (GCT) located at any suitable position. Besides, the important characteristics of these terminals that they were built to withstand earthquakes, and that are requiring a specific ground antenna design.

a. Ground earth stations (GES)

To enable continuous communication service by communication satellite, even during natural disasters, two GES can be constructed at two different positions, some 500 km apart. With a 13 m diameter ground reflector dish, the GES terminals transmit and receive signals in the Ku, Ka and C-bands. A very high effective isotropic radiated power (EIRP) of 85 dBW and a high gain-to-noise temperature (G/T) ratio of 40 dB/K are obtained in the Ku and Ka-band, which ensure very high availability of the feeder link. The L-band station similar to the SES terminals is deployed for the system measurements and observation. About 300 circuits are simultaneously available in both: transmit and receive directions. The special telecommand device are also in use for testing the spacecraft performance soon after putting in orbit and for continuous monitoring of the traffic system. Top-level operational software is implemented to configure the overall network and control its status.

b. Ship earth stations (SES)

The main components of the MTAS infrastructure are L-band SES terminals active within the coverage footprint are: Above deck equipment (ADE) as an antenna and below deck equipment (BDE) as a transceiver with peripheral equipment. The BDE voice, data and video (VDV) terminals can be fitted on the navigating bridge and cabins. The SES terminal is working via MTAS satellite constellation, providing VDV and Fax two-way service anywhere within the satellite footprint. In Figure 7 is shown shipborne digital video broadcasting-return channel via satellite (DVB-RCS) VSAT station, which two main components are as follows: Antenna dish or ADE structure and DVB-RCS satellite router (modem) with adequate peripherals or BDE terminal.

- The ADE configuration consists 3-axis stabilized Ku-band reflector antenna dish with automatic satellite tracking and polarization control with a wide range of azimuths, one transmitter operating at 4W Ku-band and one Ku-band LNB receiver, 0.2o peak mispointing, interface between ADE and BDE is via 2 coaxial cables, power usage is about 100 W (115/230 VAC), plastic antenna radome with reflector dish is about 114 kg, antenna height is about 149 cm and its diameter is up to 125 cm.
- The BDE configuration contains DVB-RCS satellite modem, Ethernet Hub and router, telephone adaptor for VoIP, telephone unit, single or multiple PC configured in LAN onboard ship, antenna cables and power usage of about 200 W (115/230 VAC). The DVB-RCS satellite antenna is interfaced to the ship gyrocompass device and antenna control equipment (ACE) with Rx signal divider for ACE and DVB-RCS, which manage tracking and operational capabilities of the satellite antenna.

c. Satellite control stations (SCS)

Satellite control stations (SCS) is usually situated in the building where the GES terminal is located and uses the ground antenna of the similar diameter. The main function of SCS terminal is to control the satellite throughout and its functional life within the network. This system uses two satellite frequency bands such as at: S-band in normal functional operations and Unified S-band (USB) is in use while the satellite is being transferred to its final orbit, or in the case of an emergency situation when satellite loses its altitude. In such a way, the EIRP in S-band is 84 dBV and for security purposes the EIRP on USB reaches value of 104 dBV. An SCS terminal displays the satellite's status and arranges telemetry, tracking and command (TT&C) to the GES communication satellites. Besides, the satellite position is measured very precise (within 10 m) using a trilateral ranging system instead of measuring a single signal, which is transmitted towards satellite then returned to ground terminals. Furthermore, the SCS terminal send two additional signals, which the satellite re-broadcasts to two dedicated ranging ground stations and also sends back the same signals to the SCS terminal. This technique allows the position of the satellite to be measured in three dimensions. On the other hand, a specific dynamic simulator onboard satellite is also provided to check TT&C operations.

d. GNSS System

GNSS System presented as the MTAS for maritime applications includes a large number of GMS, GCS, GES terminals and several geostationary ranging stations (GRS) with special function to establish a wide triangular observation platform for GEO satellite ranging. The GMS terminals are usually very small and autonomous located in an adequate building, external satellite dish antenna configuration and skilled staff. Each GMS calculates its position via GPS/GLONASS (GNSS) and MTAS communication signals over the satellite coverage area. All differences between computed and actual positions are used by the system to provide corrections of the satellite data. The data is sent to the GCS via telecommunications network (TTN) or satellite links, while the GCS terminal collects all information from each GMS terminals. The adequate software computes the position and internal times of all GNSS and MTAS spacecraft. In the GNSS signals is included the status of the GNSS spacecraft and its corrections, then it is computed and sent to the GES terminal for retransmission to MTAS communication satellites [2, 4, 6, 23-25].

5. CONCLUSION

The GDSS and RSAS satellite networks is designed to identify the future fissile possibilities for further enhancement of the global space (radio and satellite) CNS systems, safety, security and control of ships, freight of goods, saving crew and passengers lives, including SAR service according to IMO and SOLAS regulations and recommendations. The new established maritime CNS system deploying GEO satellite constellations with communication and navigation (GNSS) payloads for enhanced STC/STM solutions is projected to assist safe and efficiency navigation of oceangoing ships at open sea, during approaching to the anchorages and inside of seaports. The possible priority and future enhancements in the development of MTAS network will assist STC/STM to manage increased maritime traffic, to improve safety and security at sea with future reducing the infrastructures needed at shore. The already deployed GEO satellite communication payloads usually exploit transponders working on RF of L/C, Ku-band, while recently projected GEO satellite transponders are using Ka-bands for DVB-RCS transmission scenario. Since current Ku-band satellite transponders are experiencing some propagation problems during transmision and because it is not economical solution, the new proposed and already implemented Ka-band will replace Ku-band in maritime and all mobile industries.

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