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ANALYSIS OF ELECTRONIC CHART AND INFORMATION DISPLAY, SHIP IDENTIFICATION SYSTEMS AND RADAR IN ORDER TO INCREASE THE ENERGY EFFICIENCY OF A MARITIME VESSEL

B. Asalomia [1] Ghe. Samoilescu [2] A.R.Bordianu[3] E.H. Kaiter[4]
[1]CLC Eng., Military Technical Academy, Bucharest
[2]PhD. Professor, Department of Electrical Engineering and Naval Electronics, Faculty of Marine Engineering, "Mircea cel Batran" Naval Academy, Constanta, Romania
[3]Lecturer, Department of Electrotechnics, Faculty of Electrical Engineering,University Politehnica of Bucharest, Romania
[4]Lecturer, Department of Electrical Engineering and Naval Electronics, Faculty of Marine Engineering, "Mircea cel Batran" Naval Academy, Constanta, Romania

Email: asalomiabogdan@yahoo.com;gheorghe.samoilescu@anmb.ro;
adelina.bordianu@upb.ro;edith.kaiter@anmb.ro

Abstract. This paper puts into discussion the navigation integrated deck and its components. The role of AIS (Automatic Identification System) is presented. The radar with its characteristics is analyzed and starting from the block diagram, a characterization of its role within the integrated deck is carried out. An IT model for navigation radar and ECDIS (Electronic Chart Display and Information System) was developed.

Key Words: navigation radar, electronic chart display and information system, automatic identification system

1. Introduction

A navigation integrated deck consists of the following components: ECDIS monitors - ensure the display of electronic charts on which navigation is monitored and navigation information is presented; the coning monitor - sums up the functions necessary to govern the ship - the connection block of ship governing data – time, ship position, longitude; latitude, true course, course over the bottom, speed through the water, speed over the bottom, water depth under the keel, distance travelled, drift, wind, water current, tide, rudder angle, number of propeller revolutions, bearing; satellite navigation system receivers; AIS monitor - ensures the presentation of static and dynamic information regarding targets within the visibility range; GMDSS (Global Maritime Distress and Safety System) console - ensures communications within the global maritime safety system in case of danger; VHF (Very High Frequency) radio link console; ship's light console; radar monitors - provide radar surveillance and information necessary to avoid collision; indicators of the fathometer, of the Doppler loch; indicator of the number of revolutions at the propeller; rudder angle indicator; gyro repeater; navigation timer and clock onboard.

The ARPA radar (Automatic Radar Plotting Aid) is the navigation equipment used for discovering naval targets, determining their relative position by bearing and distance and calculating the movement parameters, the way and the speed, and it is the navigation radar equipped with a calculation module specialized in solving collision avoidance problems at sea. ARPA radars installed on board civil ships operate in the S band (2.9 ÷ 3.1 GHz, λ=10 m) and in the X band (9.3 ÷ 9.5 GHz. λ =3 m). The transmit power of ARPA radars is of 4 to 60 kW, typically of 10 kW to 25 kW. The repetition frequency of the pps radar signal is between 350 and 3000 pulses/second - fig.1[1,2].

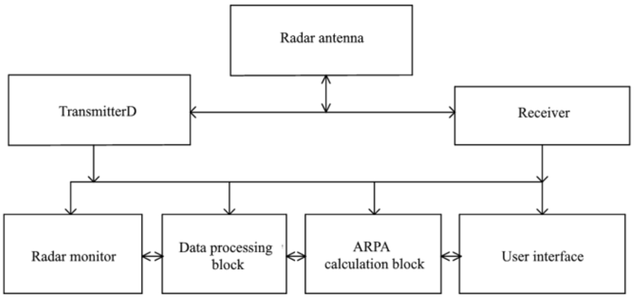

Fig. 1. Radar block diagram

The radar antenna fulfils the role of both emission and reception of radar signals (ultra-high frequency radar pulses). Radar emission is circular, in the form of a beam directed by electromagnetic waves - lobe with an opening of 10 ÷ 20 horizontally and 200 vertically. The antenna has a rotation movement of 20 ÷ 40 rotations/minute. The reception block amplifies the signals received by the antenna, where they are analyzed and processed to eliminate errors due to the reflection phenomenon die and the influence of parasitic signals, due to the existence of other radar emissions, some obstacles due to relief forms and unfavorable weather conditions. The ARPA processing block performs: the acquisition and tracking of manually or automatically selected naval targets, depending on their degree of danger; calculation of real and relative movement parameters. The radar screen and the user interface provide the necessary commands for working with the radar: choosing the type of radar image; working distance; acquisition of targets; measurement of reliefs and radar distances, etc.

The wavelength of the radar signal - λ and the effective radar reflection surface - σ are defined by the relations $\lambda = c/f_1$ and $\sigma = 4\pi d^2(S_2/S_1)$, where: c is the speed of light; f_i – frequency of pulse oscillations; d – power flow density at the target, S_1 – power flow density at the target; S_2 – density of the power flow arriving at the receiver.

The functional blocks of a radar transmitter are: the modulator which forms well determined pulses; the ultra-high frequency generator; the energy source; the synchronizer (trigger) which synchronizes the operation of the component blocks of the radar.

The receiver of an ARPA radar has the following technical characteristics: wavelength λ or frequency f; pulse duration τ_i; repetition frequency F; admissible front of the pulse at the output of the receiver t_f; sensitivity; output voltage of the receiver U_{out}; adjustment devices.

Using the ECDIS system together with the ARPA radar ensures the increase of navigation safety, and the avoidance of collision at sea. The correct and efficient use of the radar and the AIS system ensures during navigation [2]:

1. the radar: checking the alignment of the bow line and the giro road; checking the correct overlap of the radar information with that of the electronic map; regularly checking the accuracy of the purchase, plotting targets and alerts; periodic verification of the quality of equipment operation; verification of AIS information with the radar image and with visual observations; adjusting the reception depending on the state of the sea and meteorological conditions; setting navigation conditions.[3]

2. The AIS: updating data about the ship's voyage and navigation data; checking the accuracy of the dynamic or static data of your own ship; special checks for reception, transmission and content of AIS binary messages; checking the situation of abnormal functioning or in case of malfunction.

The data obtained from the radar can be used to add extra information that can improve ECDIs performance, by example by verifying the navigational system.

A comparison of the technical possibilities of AIS-radar (Automatic Identification System) makes it possible to understand the optimal ways of using navigation equipment [1, 3, 4].

2. The computer model for the navigation radar and ECDIS

In Commercial ships are equipped with radar equipment that can work in S and X band, and they can detect targets, among which we can mention, any floating objects (island, rocks, iceberg, etc.) or other ships and obstacles which can display information on the screen, such as the distance of the ship from the target, this to be able to avoid collision with them. The radar in the band X must detect SART (Search and Rescue Transponder) equipment as well as radar buoys. Then when the own vessel is stationary, in calm sea, for a height of 15m radar antenna, the detection minimum distance of one navigational buoy must be at least 40 m (horizontal distance measured from the position of the antenna). At the same time, a buoy, in the same situation, must be detected from 1 nautical mile, without changing the scale or the operation mode of the radar. The radar is the vital equipment for maintaining the navigation security, this one providing information to the watch-keeping officer about the vessels motion and their location related to the own ship, as well as the position of the obstacles and of the signaling measures for safety navigation. Radars with an automatic plotting system (ARPA) automatically allow information about targets and their simultaneous monitoring, providing a clear picture of the navigation situation and warning the watch-keeping officer in time, related to the appearance of a dangerous situations.

The ECDIS equipment and other equipment required for its optimal operation must be able to be powered from an emergency power source, in accordance with the requirements stipulated in chapter II-1 of the SOLAS 1974 convention. Changing the power source or interrupting the power supply in a time interval of 45 seconds shall not cause manual reset of the equipment.

The electronic chart information system - ECDIS is a computerized navigation system, consisting mainly of a processor and a display, a standardized database and navigation sensors. ECDIS is not only a real-time navigation information display system, but can support many other functions such as: voyage planning, voyage monitoring and a whole range of alarms. Sensors that could interface with an ECDIS are radar, Navtex, automatic identification systems and depth sounders.

This equipment is designed and built to satisfy all the requirements rigorous imposed by classification societies or by international organizations, by meeting some sea safety criteria and exploitation. The new devices contain and have been designed with different protection against cyber-attacks. These attacks can affect them because they are permanently connected to the ship's internet network. This login need is due to the fact that the system must receive constantly real - time information regarding the navigation route as well electronic map updates.

Technical specifications – power supply for the radar component (fig.2):

A). Processor unit (w/ antenna unit)   - 100-230 VAC (3.0-1.5 (5.8-2.6) A, 1 phase, 50-60 Hz), 42 rpm
B). Monitor unit / Main monitor: MU-270W - 100-230 VAC (0.7-0.4 A, 1 phase, 50-60 Hz) or 12-24 VDC

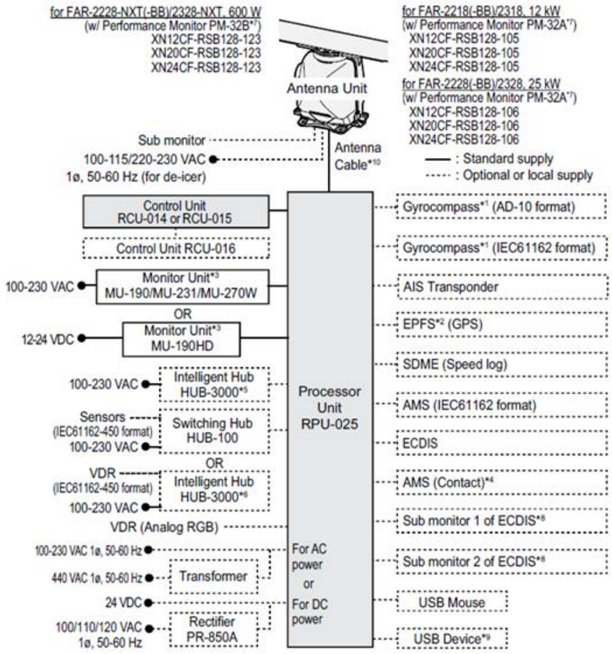

Fig. 2. Radar component elements presentation scheme.

Technical specifications – power supply for the ECDIS component (fig. 3):
A). Monitor unit / Main monitor: MU-270W   - 100-230 VAC (0.7-0.4 A, 1 phase, 50/60 Hz)
B). Processor unit - 100-115/220-230 VAC (1.5-0.7 A,   1 phase, 50/60 Hz)

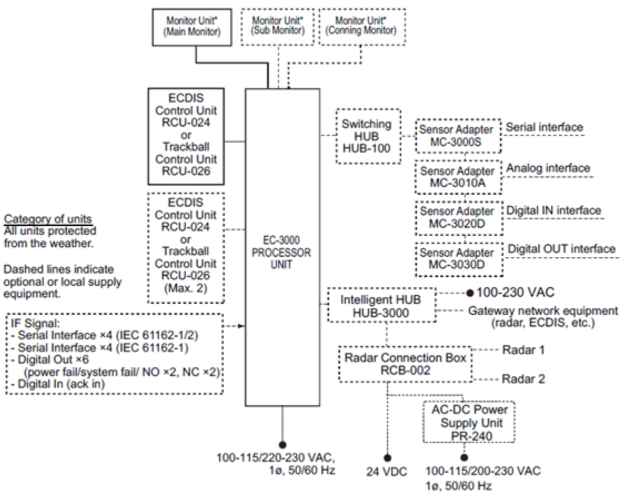

Fig. 3 Schematic presentation of ECDIS component elements.

The mathematical pattern for the radar in the band X with 220V power supply is used in the design and implementation of the simulator for signal processing and is based on the Doppler and Borden method [5].

The transmitted signal is characterized by a simple form of variation in the form of a sinusoidal oscillation, thus being represented by the following relationship:

$$s(t) = w(t) \cdot \cos(2\pi \cdot (f_c \cdot t + \phi(t)) \quad (1)$$

, where w(t) is the wave amplitude modulation, $\phi(t)$ represents the modulating frequency or phase, and f_c is the standard established frequency.

It is very important to note that all transmitted and received signals are based on simulated values, but which are close (90%) to real values. The representation of the signal can be realized as the result of the amplitude modulation of two sinusoids in opposite phase (different from $\pi/2$) therefore the following relation represents the quintessence of the signal representation for X-band radars:

$$s(t) = w(t) \cdot \cos(2\pi \cdot \phi(t)) \cdot \cos(2\pi \cdot f_c \cdot t) - w(t) \cdot \sin(2\pi \cdot \phi(t)) \cdot \sin(2\pi \cdot f_c \cdot t) \quad (2)$$

The complex form of the relationship s(t) is $s(t) = R(w(t) \cdot e^{2\pi\phi(t)} \cdot e^{2\pi \cdot fc \cdot t})$, with wave given w(t) as a real value.

We obtain the following relation which is also used for the practical simulator:

$$s_0(t) = w(t) \cdot e^{2\pi\phi(t)} \quad (3)$$

The linear signal, as an emitted signal, can be written using the relation:

$$S = \cos\,(2\pi f_0 t + \pi R t^2) \quad (4)$$

, where f_0 stands for the initial frequency and R for the noise rate.

Another important aspect used in the simulation of signals and their practical illustration, is their analysis when the target location is placed in the direction of the beam and the wave is reflected and received by the antenna. The reference $\sim S_r$ signal and the echo signal $\sim S_b$ can be expressed using the following expression:

$$S_r = \cos(2\pi f_o t + \pi R t^2) \quad (5)$$

$$S_b = \cos\,(2\pi f_0 t(t + \delta t + \delta\tau) + \pi R(t + \delta t + \delta\tau)^2 + \epsilon) \quad (6)$$

, where: δt represents the delay time of the optical fibre, $\delta\tau$ is the free space delay pulse, ϵ is the initial phase depending on the time delay between the line differences TTD (True Time Delay).

The X-Band Radar simulation result is presented in Fig. 4.

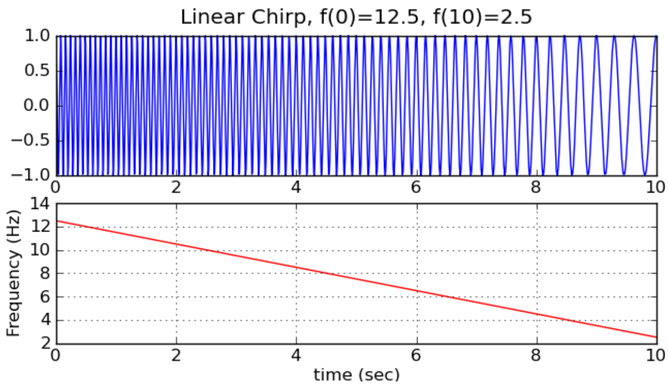

Fig. 4. X-Band Radar simulation result.

We started from the mathematical relationships used in ECDIS systems. The same form of the following relations was used while implementing the simulator. The relations are:

$$s_1(t) = s_2(t) = \left(\frac{\sin t}{t}\right)^n \sin\,(2\pi n t) \quad (7)$$

$$s_1'(t) = s_2'(t) = \left(\frac{\sin t}{t}\right)^n \cos\,(2\pi n t) \quad (8)$$

The simulation of the ECDIS computer system is presented in Fig. 5.

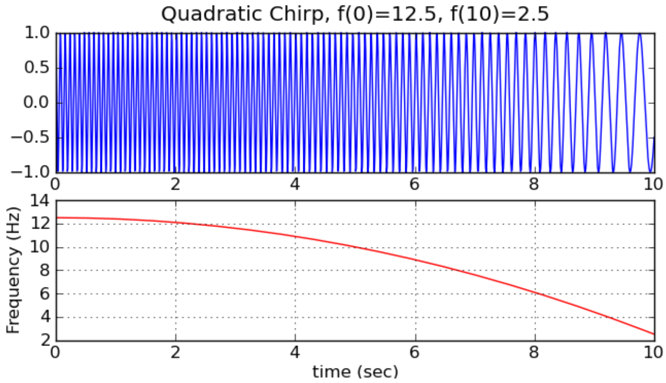

Fig. 5. Simulation of the ECDIS computer system

An ECDIS is a geographic information system used for navigation and which complies with the IMO (International Maritime Organization) regulations as an alternative to nautical paper diagrams. The ECDIS uses the GPS (Global Positioning System) to pinpoint the navigational points. One can say that ECDIS is a navigational information system, combined with other navigational equipment such as the GPS, the AIS, the radar and automatic radar plotting aid (ARPA), the ships gyro-compass the echo sounder etc.

3.Effective management of navigation equipment

An efficient use of energy is based on better knowledge of energy consumption. It is important to maintain an energy management system that monitors, analyses and communicates the energy consumption having as purpose improving of energy effectiveness. An inventory of equipment that consume energy must be available and updated continuously. This must include: equipment type, function, location and nominal power. This is why the principle of the six keys of an energetic management system on a ship is applied – management commitment; significant users of energy; power performance indicators; opportunities list to improve the energy performance; operational control; verification – with customization for navigation equipment. The concept of the energy management solution consists of: consumers monitoring and optimizations of electrical power consumption; implementation of automatic consumption reporting systems; avoiding load peaks, by automatically programming the consumers activity; using the lighting control system with LEDs instead of fluorescent tubes; replacing energy-consuming equipment with products that have a lower energy consumption; the use of presence sensors for the operation of the lighting system and of measurement and control equipment; integrating renewable energy sources into the supply system; implementing an energy management software application [6,7,8].

4. Conclusion

An efficient use of energy is based on better knowledge of energy consumption. In order to achieve electrical efficiency it is important to use energy efficient motors, components with low energy consumption, slip power recovery systems all integrated in an intelligent computer system. It is important to maintain an energy management system that monitors, analyses and communicates energy consumption having as purpose improving of energy effectiveness. An inventory of equipment that consumes energy must be available and updated continuously. This must include: equipment type, function, location and nominal power. This is why the principle of the six keys of an energetic management system on a ship is applied – management commitment; significant users of energy; power performance indicators; opportunities list to improve the energy performance; operational control; verification – with customization for navigation equipment.

ECDIS as an intelligent system, which combines different functions in a computerized system, it can be programmed to issue alarms or display warnings when some parameters reach or exceed the limits imposed in order to monitor and avoid navigational hazards. The IMO standards require the following alarms to exist on the ECDIS: deviation from the established route; using a different positioning system than the one of the system; approaching a critical point; exceeding the established road limits; displaying maps at different scales; failure of the positioning system; vessels crossing the safety contour.

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