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USING HFSW RADAR, INTO 21-CENTURY MEXICO'S NAVY OPERATIONS.

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ABSTRACT

Mexico's Navy mission is to employ the naval military power of the Mexican Federation for the interior security and external defense of the country. That mission must be achieved by performing operations with scarce resources, due to financial constrains. The Exclusive Economic Zone (EEZ) of Mexico is about 1.6 times the size of its continental territory, for what it is necessary to employ new detection technology, in order to preserve the national sovereignty over such area. The High Frequency Surface Wave Radar could be the tool Mexico's Navy needs to achieve that goal into the 21-Century, because it allows to perform operations in the EEZ with a better concentration of effort and economy of resources.

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INTRODUCTION.

Mexico's Navy today finds itself in a process of significant transformation, in order to face up the requirements imposed by its mission and the demands of a "globalized" world that changes rapidly.

One of the challenges that this transformation entails is to attain operating efficiency, in order to accomplish the mission imposed by the Political Constitution, utilizing the least possible number of resources.

A new type of radar has been developed in Canada, which permits the detection of maritime targets within a range of 200 nautical miles from the coastline. This radar allows a continuous surveillance over the Exclusive Economic Zone (EEZ).

Modern technology, in the form of a High Frequency Surface Wave Radar (HFSWR) has the potential to allow Mexico's Navy to meet the challenges that globalization poses to the security and enforcement of Mexico's EEZ, in a resource constrained environment.

Surveillance satellites could provide another alternative to survey the EEZ, but their employ was not considered, because the use of such technology is beyond the scope of this paper.

This paper analyzes the present-day situation of Mexico's Navy operations, as well as the functions and capabilities of the High Frequency Surface Wave Radar (HFSWR) with the aim to determine its utility for the improvement of such operations and to propose the best way to install it on Mexican coasts.

LEGAL FRAMEWORK OF THE MEXICO'S NAVY

Mexico's Navy is a National Military Institution of permanent character, whose mission is: To employ the Naval Power of the Federation for the internal security and the exterior defense of the country[1].

Starting from this mission, in the Internal Regulations of the Secretary of the Navy, the following becomes established as a non-delegated duty of the Secretary of the Navy:

> To exert the High Command of Mexico's Navy and to administrate the naval power of the Federation, determining and directing the doctrine, policy and naval military strategy, for the interior security and external defense of the country, and to support the maritime national development.

This role makes the Secretary of the Navy responsible for the Institution's responsibilities, as they are stated in the Organizational Law of the Secretary of the Navy. A summary of those responsibilities related with the naval operations, are described as follows:

1.- To organize, train, make ready, equip and operate the constituting forces of the Secretary of the Navy, for the fulfillment of its mission and the exercise of its functions.

2.- To exert naval military jurisdiction on behalf of the Federation on the Territorial Sea, Economic Exclusive Zone, Coastal Zone[2], Islands, Keys, Reefs and Continental Shelf, including the correspondent airspaces.

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[1] Organic Law of Mexico's Navy, published in the Official Newspaper of the Federation on Dec. 24, 1993.

[2] Presidential edict on Sep. 8, 1941, "…a strip of national territory of 10 km wide, starting at the medium tidal line…"

3.- To perform operations of search, rescue and salvage at sea.

4.- To survey the maritime, pluvial and lacustrine natural resources.

5.- To Support the Office of the Public Attorney of the Federation in order to combat terrorism, smuggling and trafficking of people, guns, narcotics and drugs, in the terms of the applicable legal provisions.

6.- To intervene in the prevention and control of maritime contamination, as well as in the surveillance and protection of the maritime space within its area of responsibility; acting by itself or in association with other national or foreign Institutions.

The strategic objectives established for the President of the Republic, Supreme Commandant of the Armed Forces in the National Development Plan, 2001-2006, provide the direction for the Secretary of the Navy in the fulfillment of the mission and responsibilities of Mexico's Navy, these objectives are:

1.- To preserve the sovereignty of our territory.

2.- To develop in a harmonic and balanced way, the response capability of the Armed Forces, strengthening their participation, operating coordination and process of modernization, in accordance with the priorities of national security.

3.- To improve the mechanisms of interinstitutional coordination and cooperation into the framework of the public security, in order to guarantee the security that the society demands.

Having established the way ahead, the Secretary of the Navy enunciated his vision 2006[3] of the Mexico's Navy; witch contains the middle term institutional goals, as follows:

[3] Secretary of the Navy. Second Labor Report 2001-2002, pag. 3.

> A Naval power supporting the achievement and maintenance of the national maritime objectives, that guides the maritime national development; with a modern logistic infrastructure capable to operate at all times, with oceanic and territorial waters surveillance ships designed and constructed in Mexico and two Naval Forces executing naval operations with naval warfare inherent tactics, being capable to take part in international peacekeeping operations and operations of training with friendly countries, when required by national interests.

Mexico's Navy Chief of Staff supports the Secretary of the Navy in the fulfillment of the responsibilities mentioned above, according to the functions that he has assigned by the Internal Regulations of the Secretary of the Navy. The functions related with the naval operations are summarized as follows:

1.- To advise and assist the High Command in the planning and coordination of the actions to fulfill the responsibilities assigned to Mexico's Navy, transforming his decisions in directives, orders and instructions and supervising their fulfillment.

2.- To obtain, process and distribute information of strategic and operation concern, for the fulfillment of the mission and responsibilities of Mexico's Navy.

3.- To perform the linkage and coordination of the secretary's office with the national and international armed forces and institutions.

4.- To study and propose the geostrategic organization of the Naval Regions and Zones, in the terms marked by the correspondent legislation, as well as the display of the operating units.

5.- To determine, disseminate and supervise the operational and training doctrine of the operating units.

6.- To formulate and keep updated the plans to guarantee the external defense and the interior security of the country in the sphere of his responsibility, coordinating with others institutions and entities the elaboration of such plans.

7.- To establish and disseminate the naval planning doctrine to the units and establishments of the Mexico's Navy's.

8.- To evaluate the results of the actions of Mexico's Navy, in order to optimize the use of resources and to feed back planning process.

According to the Law and Regulations outlined above, it is possible to infer that the Chief of Naval Staff performs operational level planning in order to assist the Secretary of the Navy to attain the national strategic objectives established for the Supreme Commandant (President of the Republic). The tactical level is executed for the Naval Forces, Regions, Zones and their subordinates operational units located on both of the country's coasts.

The Operations Theater consists of the Coastal Zone, the Territorial Sea and the Economic Exclusive Zone. The Costal Zone extends across the 11,122 km of littoral that Mexico counts with, located at the Pacific Ocean, Gulf of Mexico and Caribbean Sea. The Territorial Sea extends 12 miles[4] into the sea from the littoral line, while the Economic Exclusive Zone does it for 200 miles[5]. The Exclusive Economic Zone of Mexico (Fig. 1) comprises an area of 3,149,920 km^2, which is about 1.6 times the territorial surface of the country[6]. An area of this magnitude requires a great quantity of resources to exercise national sovereignty over it.

[4] Geneva Convention about the Territorial Sea and the Contiguous Zone of 29 April 1958. Overview.

[5] United Nations Convention on the Law of the Sea of 10 December 1982. Overview.

[6] National Institute of Geography and Statistics (INEGI.) Geographic Information of México. Basic Data. www.inegi.gob.mx/difusión/español/figdatb.html.

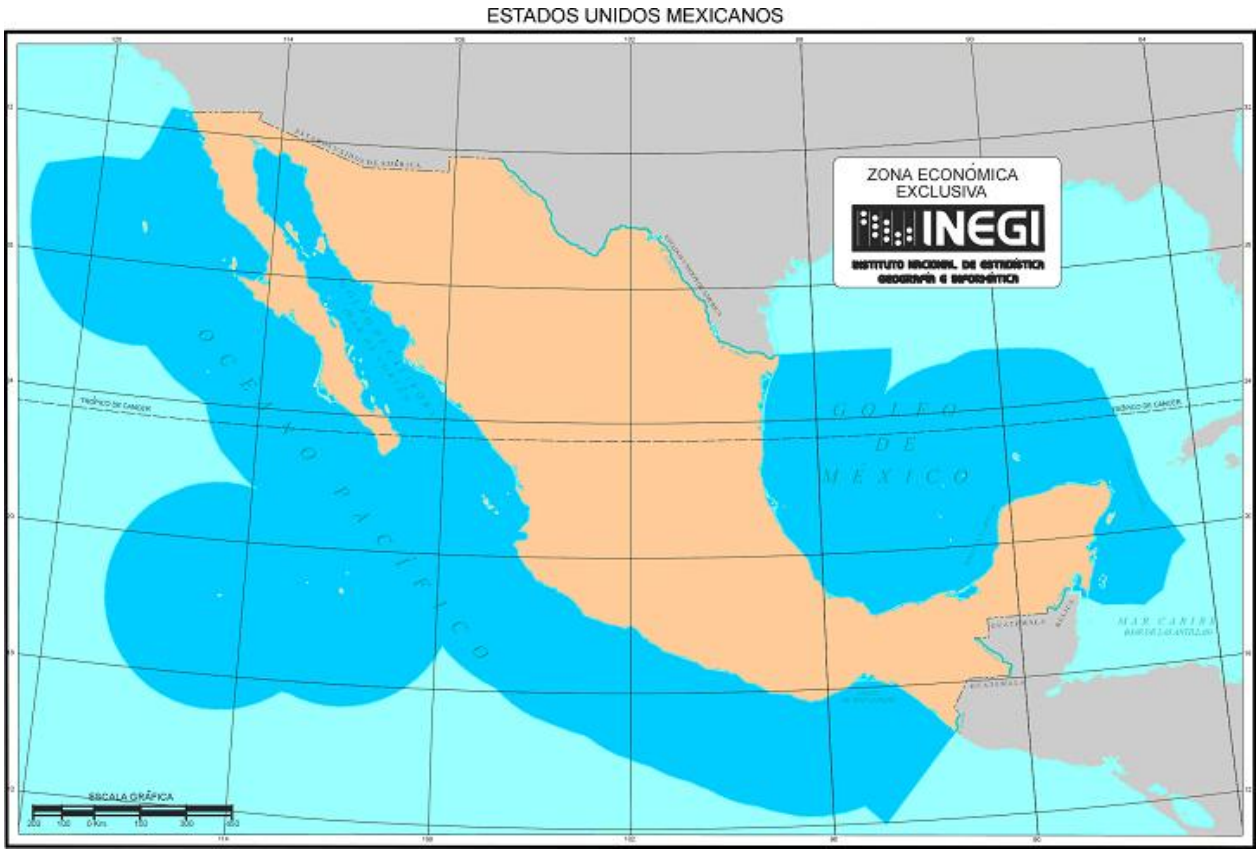

Fig. 1. Mexico's EEZ.

of the commandants of region, zones, sectors, sub sectors and naval posts. In like manner, there are four groups of Marine Corps assigned to provide security to the strategic facilities of Mexican Petroleum, Federal Electricity Commission and others vital companies and infrastructure for the country.

In order to accomplish all tasks required, the employment of operating units has been rationalized according to the geographic jurisdictional space, distributing them in critical areas of the national seas (Fig. 2), which encompass a higher probability of criminal activity. The effort of the operating units is concentrated in these areas of concern[7]:

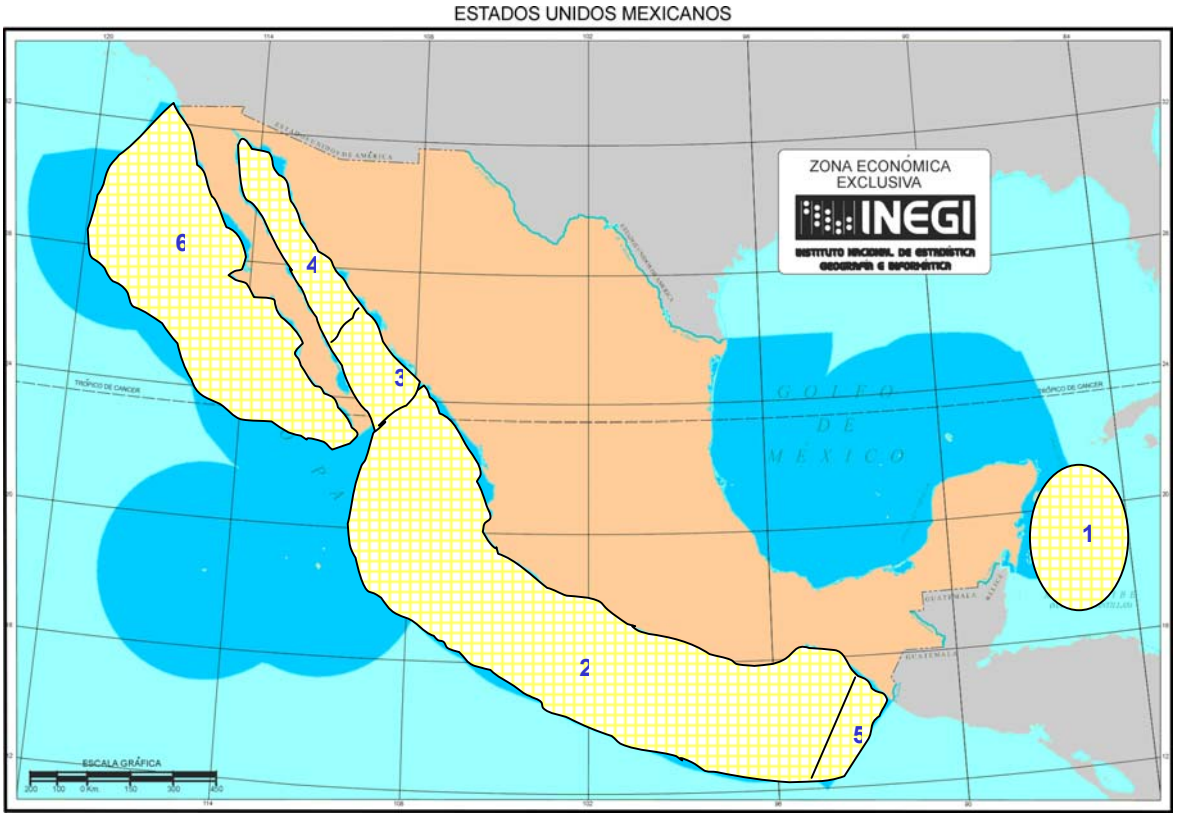

Fig. 2. Areas of concern.

[7] Navy General Staff. "The naval operations in the Mexico's Navy". Document received by e-mail, 29 Sept.. 2002.

1.- Caribbean Sea (drug trafficking).

2.- Economic exclusive zone in front of the coasts of Chiapas, Oaxaca, Guerrero, Michoacán, Nayarit (drug trafficking).

3.- Sinaloa's coasts (assaults to fishing and tourist boats, preservation of marine resources and safeguard of human life at sea).

4.- Gulf of California (drug trafficking, assaults, illegal fishing and safeguard of human life at sea).

5.- Maritime frontier with Guatemala (drug trafficking, illegal immigration and illegal fishing).

6.- West coast of Baja California (illegal immigration and safeguard of human life at sea).

During the period of September 1, 2001 to August 31, 2002, a total of 11,716 operations within the Economic Exclusive Zone, Territorial Sea and Coastal Zone have been accomplished, with the average monthly participation of 10,750 elements deployed on these areas. Said operations corresponded to: 4,804 of patrol and vigilance; 440 of preservation of the maritime resources; 2,377 of support, salvage, and search and rescue, and 4,095 to combat against drug trafficking[8]. To perform such operations, the surface units navigated 1,619,000 nautical miles and the naval aviation units flew 2,486,000 nautical miles[9].

The patrol and surveillance operations, as well as the ones belonging to combat against drug trafficking, constitute over 80 % of the total. These operations require a continuous presence of ships and aircraft in the Exclusive Economic Zone.

[8] Secretary of the Navy. Second Labor Report 2001-2002, pag. 23. http://www.semar.gob.mx/ infolab.pdf

The cost to achieve that objective is very high, for example, the average operating cost of an patrol aircraft is about ($10,000 USD per hour[10]), which imposes severe limitations on the time that asset is utilized for patrol duties. For that reason, it has not been possible to achieve the goal to keep 10 ships deployed continuously on the Exclusive Economic Zone, in order to preserve the sovereignty. Only 8 ships are deployed continuously on the EEZ[11].

The above statistics clearly show that effective surveillance and control of such a vast area is simply not possible given the current resource constraints. What is needed is a much improved surveillance capability that will allow the limited number of operational units to concentrate their efforts where their presence can be effective. Modern technology offers a cost effective solution to this challenge

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[9] Id. Pag. 23.

[10] Raytheon Systems Canada Ltd. "SWR-503 High Frequency Surface Wave Radar Comprehensive Surveillance of the Exclusive Economic Zone (EEZ)". Operation cost for a patrol aircraft P3. Pag. 3.

[11] Secretary of the Navy. Second Labor Report 2001-2002, pag.17. http://www.semar.gob.mx/ infolab.pdf

ANALYSIS OF THE HFSW RADAR

Basic Theory of Radar.

The RAdio Detection And Ranging (RADAR) is the designation of an electronic system that allows to detect objects beyond of the line of sight and to determine the distance at its position, by projecting on them radio waves[12].

The radar system constitutes a transmitter, a receiver and a display. The transmitter broadcasts electromagnetic waves through an antenna, which concentrates the waves in a beam and directs it in the direction desired. All radar systems utilize a radio transmitter of high frequency, which emits a beam of electromagnetic radiation with a wavelength in the order of some centimeters to one meter. The objects that are in line with the beams trajectory reflect the radio waves back toward the transmitter.

The atmospheric layer known as the Ionosphere plays a very important role in the functioning of the Radar, because it reflects the electromagnetic waves emitted by the transmitter and does not allow that such waves get lost into the space. However, the condition of the Ionosphere change according to the time of day, the time of year, solar activity and geographic location, which affects the way that the electromagnetic beams propagate.

When the waves collide with an object, some energy is reflected forming a signal of an echo. The antenna perceives the energy contained in that signal and sends it to the receiver.

The functioning of the radar implies for the transmitter to emit a great quantity of energy, receiving and processing a very small fraction of that energy, which is returned in the shape of echo. To solve the problem of detecting a very small echo, in the

presence of the enormous signal emitted, a system of impulses is utilized. An impulse of energy is emitted during the lapse of 0.1 to 5 microseconds; the transmitter then is off during a period of a hundredth or thousandths of microsecond. The Duplexer is the component of the radar, which is in charge of getting connected alternately to the antenna, with the transmitter and the receiver.

The Doppler radar transmits a constant-frequency, continuous wavelength beam. The signals reflected for moving objects in relation to the antenna, will present distinct frequencies because of the Doppler effect. The difference in frequency between the transmitted and received signal is utilized to calculate the velocity of the target. If the radar's receiver is designed to reject those echoes that possess the same frequency as the signal transmitted, and only amplifies the ones belonging to Doppler shifted frequencies, then only the moving targets will be displayed.

The radar of modulated frequency (FM) emits a continuous signal whose frequency changes in a uniform way. The difference between frequencies of the signal transmitted and the echo received, permit to calculate the distance between the transmitter and the target. These systems are more accurate than the system of impulses and have longer range.

The modulation of frequency is achieved through another important component of the radar named the Modulator. The function of this device is to extract current continuously from an energy source, like a generator, in order to feed the transmitter with very precise impulses.

In the case of continuous wave radars (CW), the transmitter must work continuously, so that the receiver also must operate at the same time to detect the

[12] Microsoft Corporation. Encyclopedia Encarta 2001. “Radar”. Pag. 1,

target. To avoid interferences, it is convenient to utilize separate antennas to transmit and to receive. In order to obtain bigger possible isolation, both antennas must be separate from each other for a convenient distance[13].

Within the antenna, polarization of the signal is performed, which determines how the electromagnetic beam is projected towards space, in order of to obtain the best conditions for propagation. The vertical polarization, for example, permits the best propagation of the beam through long distances.

In the receiver, the echo's signal is processed to measure its intensity and frequency, and is sent to a high-speed computer, through an analog-to-digital Converter. In this Converter, analog signal is transformed into a sequence of ones and zeros. The computer is programmed to process that sequence and to extract the information relative to the target. This information is filtered, in order to discern interferences and to avoid the detection of false targets. The processed data is sent to a display, like a computer screen. Displays can be connected to a computer network, with which it is possible to obtain the same image at different places of monitoring.

Characteristics of the HFSW Radar.

Raytheon Canada, Limited and the Department of National Defense of Canada (DND), through the Defense Research Establishment Ottawa (DREO), developed the High Frequency Surface Wave Radar (HFSWR) jointly, in order to achieve continuous surveillance of the 200 nautical mile Exclusive Economic Zone. The experiment began in 1995, with the operation of two radar stations installed at sea level in Cape Race and

[13] Merril I. Skolnik. “INTRODUCTION TO RADAR SYSTEMS”. 2ND ed. (McGraw-Hill Inc., 1980.) Pag. 72.

Cape Bonavista, Newfoundland, working in an integrated form and operated remotely from Waterloo, Ontario[14].

What differentiates the HFSW radar from any other conventional radar is the fact that it transmits a signal of continuous wave modulated for a low value high frequency (FMCW). The Modulation of Frequency (FM) permits the utilization of one technique named pulse compression, which facilitates the transmission of long-length pulses that contain more energy. In this way it is possible to achieve a longer range, but without sacrificing the precision in the measurement of the target range. Since the signal is a continuous wave (CW), the radar system can utilize the Doppler phenomenon to separate the signal of the moving target from the background noise (clutter). The measurement of the change of frequency of the Doppler effect, allows the radar system to determine if the target itself is moving toward or away from the radar station.

In order to transmit the signal a long distance, the HFSW radar takes advantage of the electromagnetic refraction effect, that water vapor over the ocean surface causes. This water vapor creates a super refracting duct[15], which permits to the electromagnetic beam, emitted from the radar, to follow the curvature of the ocean, achieving a longer range than is possible with conventional radars.

The propagation of the electromagnetic beam on the surface of the sea, depends on its frequency in great measure. In the studies conducted during the development of this radar, it was determined that it is possible to obtain an efficient

[14] LCdr Simon Hughes. EXERCISE LEONARDO DA VINCI **HIGH FREQUENCY SURFACE WAVE RADAR. Canadian Force College CSC 28. Pag. 12/18.**

[15] Merril I. Skolnik, INTRODUCTION TO RADAR SYSTEMS 2ND ed. (McGraw-Hill Inc., 1980.) Pag.451.

propagation using low values of high frequency (HF), in the range of 3-5 Mhz[16]. Likewise, it was determined that the vertical polarization of the high-frequency waves makes possible the propagation of the electromagnetic beam over the surface of the ocean beyond the horizon, which assists in obtaining a longer range[17].

The High Frequency spectrum is crowded by civilian and military users, which is a very important reason to carefully select the radar's working frequency, in order to avoid interferences and the consequent degradation in the system performance[18].

The Ionosphere changes during nighttime decreasing its absorptive capacity, and for that reason, the signals from other distant sources along with the echo reach the antenna, causing interference. Another parameter to take into consideration is the geographic location of Mexico's territory, related with the propagation characteristics of the ionosphere. The optimum value of an HF frequency to be reflected by the ionosphere over Mexico is significantly different of those values for the location of the radar stations in Canada. The figure 3, shows the values variation for North America[19].

The characteristics of the electromagnetic beam cause impact directly on the design of the radar antenna. The HFSWR has separate antennas for transmission and reception. The transmission antenna is a single one, while the receiving antenna consists of an installed array of 32 receiving elements in a beachfront of 405 meters.

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[16] Merril I. Skolnik, INTRODUCTION TO RADAR SYSTEMS 2ND ed. (McGraw-Hill Inc., 1980.) Pag.530.

[17] Raytheon Canada, Inc. HFSWR (High-Frequency Surface Wave Radar). http:/www.raytheon. com/product.pdf. pag. 3.

[18] Simon Hughes. "EXERCISE LEONARDO DA VINCI. HIGH FREQUENCY SURFACE WAVE RADAR". Pag. 11.

[19] The Australian Space Weather Agency. IPS Radio and Space Service. IPS - North America - Ionospheric Map.htm. http://www.ips.gov.au

The great length of the reception antenna is due to the low transmission frequency used for the radar[20] and the necessity to separate the receiving elements, in order to avoid undesirable signals. The transmission antenna emits a beam of continuous wave and high frequency, which covers a sector of 120 degrees continuously.

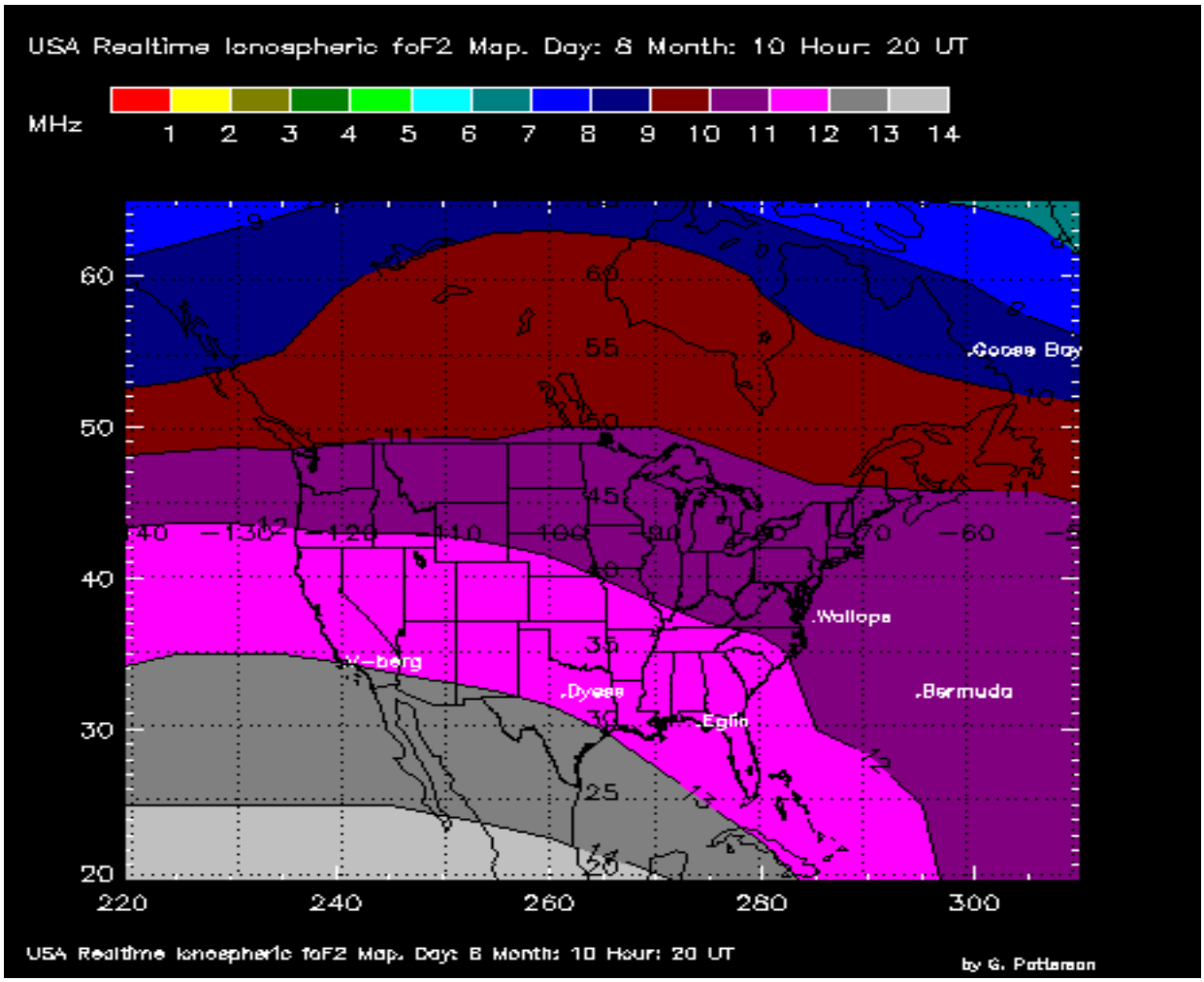

Fig. 3. Optimum values of HF reflected frequency.

For optimal performance, radar stations must be installed on areas with the least possible electric noise in accordance with specifications of the International Radio

[20] Levent Sevgi, Anthony Posford and Hing C. Chan, Part 1: Theoretical background and Numerical Simulations, An Integrate Maritime Surveillance System Based on High-Frequency Surface-Wave Radars

Consultative Committee (CCIR)[21]. In addition, the right calibration of the reception antenna is very important to that end.

Operating capability of the HFSW Radar .

From the performance testing conducted with this radar system, it is possible to obtain the following information about its operating capability:

Range.- Big ships (3000 tons or more), have been detected at a range beyond 200 nautical miles during daytime. Smaller ships (1000 tons) can be detected without problems when the sea state is low, but it is not possible to establish a range prediction for this type of target, due to variations that they show in their construction, especially in regards to the height of the superstructure. In addition, air targets were detected a long range, according with their size. Big aircrafts, like Boeing 747 were detected beyond the 200 nm, while small size targets, like a Beech King Air were detected at 80 nm at nighttime[22].

Nominal resolution is the capabilities of a radar system to distinguish between two targets close one to another. The radar detects the targets providing three parameters, namely: range, bearing and speed.

1.- The range resolution depends directly on the bandwidth of the beam transmitted. Since the HFSW radar works with a bandwidth less than 20 Hz, this resolution is estimated in 4 nautical miles.

(IEEE Antennas and Propagation Magazine, Vol. 43, No. 4, Aug 2001) pag. 38-40.

[21] Levent Sevgi, Anthony Posford and Hing C. Chan, Part 2: Operational Status and System Performance, An Integrate Maritime Surveillance System Based on High-Frequency Surface-Wave Radars (IEEE Antennas and Propagation Magazine, Vol. 43, No. 5, Aug 2001) pag. 54.

[22] Raytheon Systems Canada Ltd.SWR-503 High Frequency Surface Wave Radar Comprehensive Surveillance of the Exclusive Economic Zone (EEZ.) Pag. 4. http://www.raytheon.com/products/swr503/ref_docs/swr_503.pdf.

2.- The bearing resolution is directly proportional to the aperture size of the receiving antenna. For an array of 16 receiving elements, a resolution of 9^{o} is estimated.

3.- The speed resolution is estimated in 0.5 knots for moving targets and 0.05 knots for stationary targets.

The probability to detect 2 distinct targets matching the three parameters is not very high, however, in case of this occurs the radar will follow up the target with the bigger echo until, they get separated[23].

Probability of detection.- It is very high, utilizing the advanced signal processing techniques of this radar system.

Precision.- The position of the target can be estimated with a very high grade of precision (one tenth of the nominal resolution values), due also to the signal processing techniques of the radar system.

Integration of information.- The signals received for the radar are processed using computer technology, to be shown in the visual display screens of an Operation Control Center (OCC). In this facility, the originating information of two or more stations of HFSW radar, is integrated with the data proceeding from a variety of another sensors (aerial radars, infrared detectors, etc.) or sources of information (ships itineraries, mandatory identification by radio, etc.), in order to identify detected targets.

A Multiple Sensors Association Processor is responsible for this function, either automatically or by manual action of the operator, showing on the visual displays a

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[23] Levent Sevgi, Anthony Posford and Hing C. Chan, Part 2: Operational Status and System Performance, An Integrate Maritime Surveillance System Based on High-Frequency Surface-Wave Radars (IEEE Antennas and Propagation Magazine, Vol. 43, No. 5, Aug 2001) pag. 55.

synthesized digital image of all the targets that being tracked[24]. This information can be transmitted to another users connected to a communication network, through Internet or any other mean of communication.

Economy of operation.- The radar is capable of operating continuously 24 hours a day during the entire year. Personnel to operate the radar stations are not required, because such stations are remotely operated from the OCC. Therefore, the operation costs are reduced to approximately $120,000 USD per year[25], which is significantly less than the cost of the annual utilization of a ship or airplane to patrol the EEZ.

Cost of installation.- The facilities where this project has been developed (2 radar stations and a OCC) have an estimated cost of 13 million USD. The cost to patrol the area covered for such radar stations (utilizing airplanes and ships), is calculated in 13.5 million USD per year[26]

[24] Levent Sevgi, Anthony Posford and Hing C. Chan, Part 2: Operational Status and System Performance, An Integrate Maritime Surveillance System Based on High-Frequency Surface-Wave Radars (IEEE Antennas and Propagation Magazine, Vol. 43, No. 5, Aug 2001) pag. 57.

[25] Raytheon Systems Canada Ltd. SWR-503 High Frequency Surface Wave Radar Comprehensive Surveillance of the Exclusive Economic Zone (EEZ). http://www.raytheon.com /products/swr503/ref_docs/swr_503.pdf. pag. 3. "The annual operation cost for a USCG ship is 8 millions USD, and for a patrol aircraft P3 is 2 millions USD".

[26] LCdr Simon Hughes. EXERCISE LEONARDO DA VINCI **HIGH FREQUENCY SURFACE WAVE RADAR**. CFC. Pag. 15.

EMPLOYMENT AND INSTALLATION OF THE HFSW RADAR

The principles of Economy of Resources and Concentration of Effort are key elements to take into consideration for operations planning. In this case, Mexico's Navy needs to apply those principles wisely, due to the scarcity of resources.

Mexico's Navy currently has concentrated its efforts in five areas of concern on the Exclusive Economic Zone, as was shown in figure 1. In those areas, eight ships are deployed continuously on patrol and surveillance operations.

The capability of the HFSW radar to detect air and surface targets at a range of 200 nautical miles in the Exclusive Economic Zone, working continuously 365 days of the year with low operating cost is related directly with the operational principle of economy of resources. However, it is necessary to take into account the decrease of performance that affects to the radar during nighttime, as well as, its low capability to detect targets of less than 1,000 tons when the conditions of the sea are not optimal. Besides, it is necessary to identify the target using the operating units (ships or aircrafts) when there is not another way to do it.

Taking these parameters under consideration, the following step will meet the challenge to improve naval power projection over the Exclusive Economic Zone, using the operating units available and exploiting the capabilities of the HFSW radar system.

Firstly, it is necessary to determine the best location for installing the radar stations, according with the areas of concern. The position of the radar stations (as shown in the figure 4) was selected to obtain the best possible radar coverage, starting from the coastline, in the areas of high criminal activity. At a later time, additional radar stations could be installed, in order to cover the totality of the EEZ.

The installation of this kind of radar stations covering the Gulf of California is useless, due to its configuration. Therefore, operations will continue in that region as they are currently. On the Caribbean Sea's area of concern, the radar station could be installed in Isla Mujeres, because it offers the best radar coverage. In front of the coast of Nayarit State, the radar station could be installed in the Islas Marias archipelago, in order to obtain the best radar coverage.

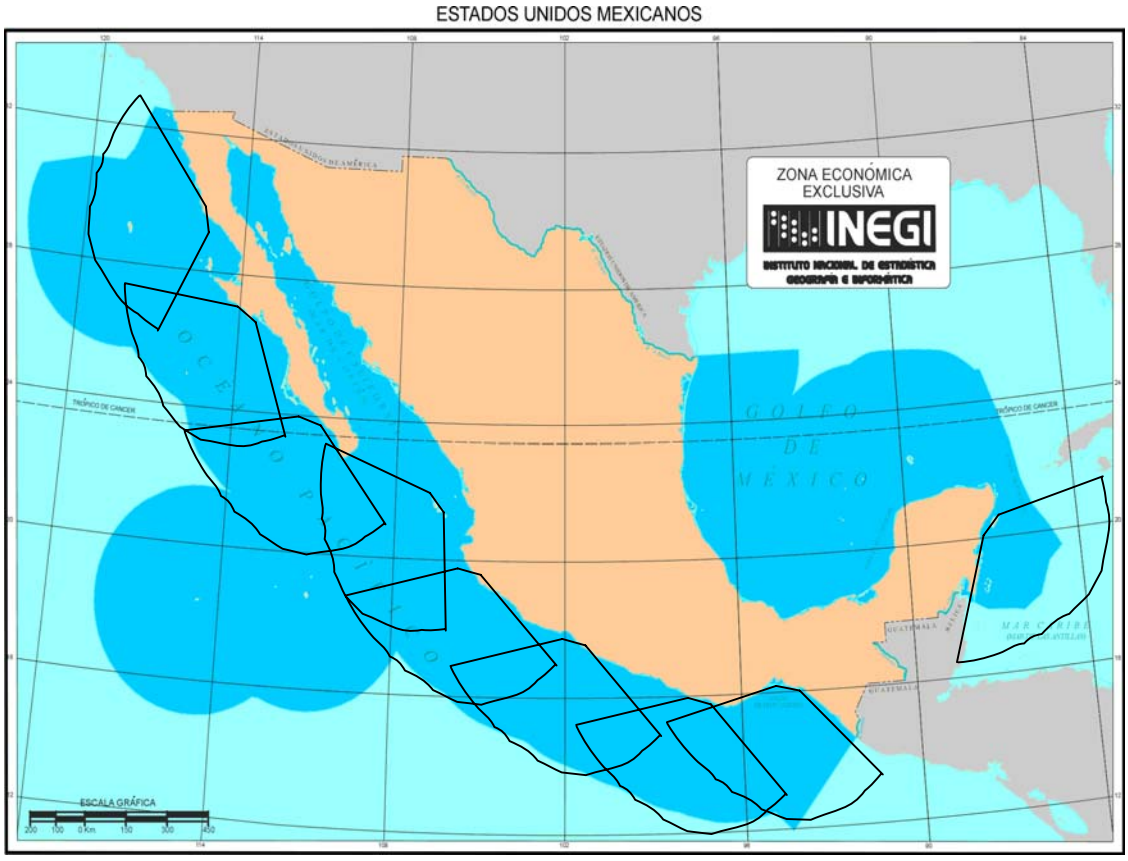

Fig. 4. Possible installation of radar stations.

After the installation of the radar stations, the next important issue is to install the communications network. The Mexico's Navy Command and Control infrastructure could be used to install the radar system's communications network with a significant

cost reduction. Besides, the Operation Control Center could be installed as an annex to Mexico's Navy Command and Control Center (C^3I), located in Mexico City, which could be connected with the local control stations, installed in the headquarters of each Naval Region and Naval Zone in control of the five areas of concern.

The capability of all operation control stations to share information with each other permits the improvement of the response time of the operational units, by receiving tracking information about suspicious targets with adequate warning. If one target moves to an adjacent area of concern, the tracking data can be transmitted to the next operation station, in order to continue with the prosecution.

Therefore, the ships continuously deployed in the EEZ can be assigned to patrol areas with the best probability of target interception using the tracking data from the most suitable operation control station.

The statistics of tracking data gathered by the radar stations, could allow Naval General Staff to assign operating units to the areas of major maritime activity, in order to concentrate the effort of such units for inspection and surveillance purposes, avoiding a waste of resources.

The "Go-Fast" boats used for drug smuggling are too small (20 m long) to be detected at long range by the radar stations. Because of that it is necessary to continue the identification process using visual means. However, if the areas of major maritime activity is identified, it could be possible to assign more units to areas where such boats pass through, increasing the probability of interception.

According to information published by Raytheon USA, about the advantages using HFSW radars, there are three models of this type of system: SWR-503, SWR-610

and SWR-1018. The characteristics of SWR-503 and SWR-1018 are known. They have different frequency of transmission and exhibit different performance regarding the capability to detect targets of different size at long ranges. While the SWR-1018 can detect an inshore trawler (12m long) at 120 nm, the SWR-503 detects the same target at 75 nm. On the other hand, the SWR-1018 can detect a large ship (190 m long) at 120 nm; the SWR-503 does it at 220 nm[27].

In both cases, the advantages derived from the operation capabilities of the HFSW radar support the principle of Economy of Resources and Concentration of Effort; however, it will be necessary to test its operational capabilities at the Mexican sites, due to the different propagation conditions of the Ionosphere over Mexico's territory. Such tests could be performed in similar ways as the tests that are being performed in the United States (using a mobile station at different locations during six months to detect small targets.)[28]

[27] Raytheon. HFSWR (High-Frequency Surface Wave Radar). Pag. 3. http://www.raytheon.com /product.pdf.

[28] Id. Pag. 2.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The Mexican government has assigned to Mexico's Navy, the responsibility to project naval power to enforce the sovereignty over the EEZ. The Naval Chief of Staff has the responsibility of planning at the operational level according with directives emanated from the Secretary of the Navy in a centralized control - decentralized execution environment. However, Mexico's Navy does not have enough resources to deploy continuously the operating units required to cover the entire EEZ. Because of that, it is necessary to improve the employment of the operational units that are deployed already.

The concentration of the operational effort on the six areas of high probability of illegal activity is a very good attempt to surpass that challenge. However, it is necessary to employ more resources to keep that areas covered continuously and to enhance the reaction time in case of a detection of illegal activities.

The High Frequency Surface Wave Radar (HFSWR), developed by Raytheon Canada Inc, has proved to be capable to detect ships and aircraft in ranges of 200 nautical miles and beyond. Besides, it has a great capability to process the information received by the radar antennas, filter it, fuse it and display it into a flexible communication network.

On the other hand, the Ionosphere affects the propagation of radar's electromagnetic beam degrading its performance during nighttime. In addition, the Ionosphere conditions over Mexican Territory and its influence over the radar performance need to be determined. However, testing and calibrating the radar antennas in the sites of installation could overcome such problems.

The installation of the HFSWR system on the coastal line, covering the areas of high probability of illegal activity allows the detection of suspicious targets with adequate warning, which permits the operating units to be prepared in anticipation, improving their reaction time. Besides, the communication network is suited to share information among the regional commands and civil agencies, in order to perform a continuous prosecution of suspicious target.

Therefore, the employ of HFSW radar system will improve the operational capability of Mexico's Navy, allowing a better use of the operational units to fulfill the institutional responsibilities. However, due to the different conditions of the Ionosphere over Mexico's territory would be convenient to test its operational capability before a definitive installation of the radar stations.

Recommendations

1.- To select the SWR-530 model over the SWR-1018, due to its better range capability.

2.- To perform an evaluation of the electric noise conditions over projected sites for radar stations installation, in order to prevent interferences at nighttime.

3.- To evaluate the operation capability of the SWR-503 system in different locations of Mexico's coastal line, to determine the optimum system calibration, according with the Ionosphere's propagation conditions.

4.- To reinforce the antenna stations basement in those locations where hurricanes and others extreme meteorological conditions could be present.

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