THE SPANISH ADVANCED MULTI – INFLUENCE NAVAL MINE MINEA

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Abstract

Modern vessels benefit from innovative designs and sophisticated coatings to reduce the underwater influences they originate. Main advances on influences reduction have been achieved for magnetic and acoustic emissions. As a response to this reduction increasingly sophisticated mines have to be developed. In this context arises MINEA, as a last-generation multi-influence mine that apart from acoustic and magnetic also detects electric, pressure and seismic influences and incorporates a sonar emissions detector.

The advanced MINEA mine has been designed and tested based on the stringent operational and performance requirements defined by the Spanish Navy and incorporates state-of-the-art signal processing algorithms implemented on reprogrammable microprocessors that allows the selection of specific targets and enhances its ability to identify and ignore minesweeping systems.

Three types of mines have been developed: cylindrical bottom mine, low profile bottom mine and moored mine. The exercise mine modality incorporates the capability of recording the detected influences, a recovering system and a ship-mine acoustic link.

Keywords: MINEA, multi – influence mine, cylindrical bottom mine, low profile bottom mine, moored mine, Magnetic Influence, Acoustic Influence, Electric Influence, Seismic Influence, Pressure Influence, SONAR Detector, UEP.

1 INTRODUCTION

All ships emit influences, which propagate through the water. These emissions can be measured using passive underwater sensors, and used to distinguish among different classes of ships or even individual ships. Such information can in turn be captured by detection systems and to facilitate the triggering of "smart" mines.

A mine's target detection device (TDD) is the electronic component that observes changes in the underwater environment in order to detect vessels and decides whether they are close enough to damage via the mine's blast effects. These detection devices can use one or a combination of different types of influence sensors to detect changes in the mines' surroundings.

Modern influence mines, whether magnetic, acoustic, seismic, underwater electric potential (UEP), pressure, or any combination thereof, may incorporate advanced technologies to improve their lethality, reliability, and versatility.

As the acoustic and magnetic signatures of naval vessels have been reduced, new types of TDD have received increased attention. Traditional acoustic, magnetic and pressure TDD have been complemented by sensors that are capable of detecting seismic and electromagnetic phenomena associated with surface ships and submarines.

MINEA is a modern naval mine that uses several kinds of influence sensors. This Advanced Multi-Influence Exercise Mine is equipped with sensors for detection and processing of all magnetic, electric, acoustic, pressure and seismic influences. A sonar detector is also included. This mine has been designed and manufactured by SAES.

SAES is a Spanish company specialized in underwater acoustics, working in three main product lines: sonar developments, mines and influence measurement systems, and onboard equipments.

The design and testing of the different versions of MINEA has been carried out in close cooperation with the Spanish Navy that has contributed with its wide experience on dealing with naval mines and underwater measurement systems.

2 PREVIOUS RELATED WORKS

SAES has a long experience in the design of naval mines: in the 90's the moored mine MO-90 was developed incorporating magnetic and acoustic influences. At the end of 90's the Underwater Multi-Influence Measurement System (UMIMS) was developed, incorporating magnetic, acoustic, pressure, electric and seismic influences.

Figure 1. MO-90 moored mine (left) and UMIMS (right)

UMIMS incorporates SAES' designed and manufactured SET-200/P electric field sensor to measure the Underwater Electric Field at sea. It is a precision, ultra low noise device that enables the measurement of very low-level electric fields. This sensor operates by measuring the voltage difference between two points in seawater. The electrodes SET2-802 are placed at such points and they act as sensing elements (differential transducer). The amplifier SET2-801 amplifies the very low level signal provided by the electrodes pair.

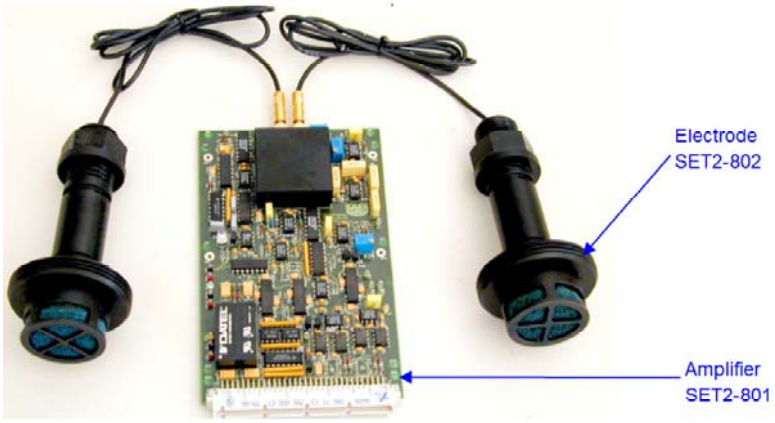

Figure 2. Electric Field Sensor SET-200/P manufactured by SAES

3 MINEA DESCRIPTION

3.1 OVERVIEW

The advanced exercise mine MINEA has been developed as a mine with the maximum detection and signal processing capabilities and with the needed facilities for training that include Recording System, Recovering System and Acoustic link to ship.

Three types of mines have been developed: cylindrical bottom mine, low profile bottom mine and moored mine. The following figure shows the three mine types developed by SAES.

Figure 3. Advanced MINEA mine types: moored mine (upper left), low profile bottom mine (upper right) and cylindrical bottom mine (lower)

The exercise mine system includes a control equipment, common for the three mine types, to configure previously the operating parameters of the mine using an infrared data link. The control equipment also enables to handle the mine along the exercise using an acoustic link, including the change of the operating parameters.

The exercise mine has not explosive charge, although its shape, dimensions and operating mode are similar to the actual combat mines with the aim to provide a realistic training system.

The mines record all influence signals, parameters and events. The recorded data recovering and also the battery recharging process can be done without opening the body of the mine.

The three mine types have common electronics and performance. They have the following common modules:

- Sensors: each sensor is composed of one or more transducers and a dedicated electronic board for data acquisition and processing.
- Central Processor: This module controls the mine operation, been its main function to process the sensor data to execute the firing algorithm. It also controls the communication between the mine and the Control Equipment.
- Acoustic Link: This module communicates the mine with the Control Equipment when the mine is submerged. The link works far from 400 meters. The Acoustic Link is used for:
    - Receiving configuration data from mother ship
    - Transmission of requested information to mother ship
    - Transmission of fire instant
    - Range measurement from mother ship to mine
- Recording System: This module records all signals, parameters and events and allows their recovery, after the exercise. This is a distributed module, located in each sensor.
- Recovery System: This module is composed of electro-mechanical devices, which enable an automatic recovery of the mine. This module is different for each type of mine.
- Safety and Arming Device (SAD): This module provides the needed safeties to arm the mine with safety.
- Visual Fire Indicator: This module is an electro-mechanical device, for launching a smoke indicator when the mine firing signal is generated.
- Power Supply Module: This module supplies the system from the batteries, generating the various supply voltages that are needed.
- Batteries: This module is composed of rechargeable lithium-ion batteries.

The mines can fit an anechoic cover to reduce the sonar target strength of the mine.

A Built – In –Test function is also included in the mine, which can be commanded from the Control Equipment via infrared link.

3.2 MINEA LOW PROFILE BOTTOM MINE

The low profile mine is a shallow seawater operating mine, against surface ships, small and medium submarines, amphibious vehicles, etc. This mine has a similar shape and dimensions than the actual combat mines.

MINEA low profile mine is a versatile multi – influence exercise mine with a shape that allows to keep the mine at the seafloor even in seawater drift presence.

This type of mine is divided on two modules. The module 'A' is a watertight compartment with positive buoyancy where the sensors, control electronics, batteries, etc. are located. The module 'B' is the ballast and includes the rope reel for recovering purposes.

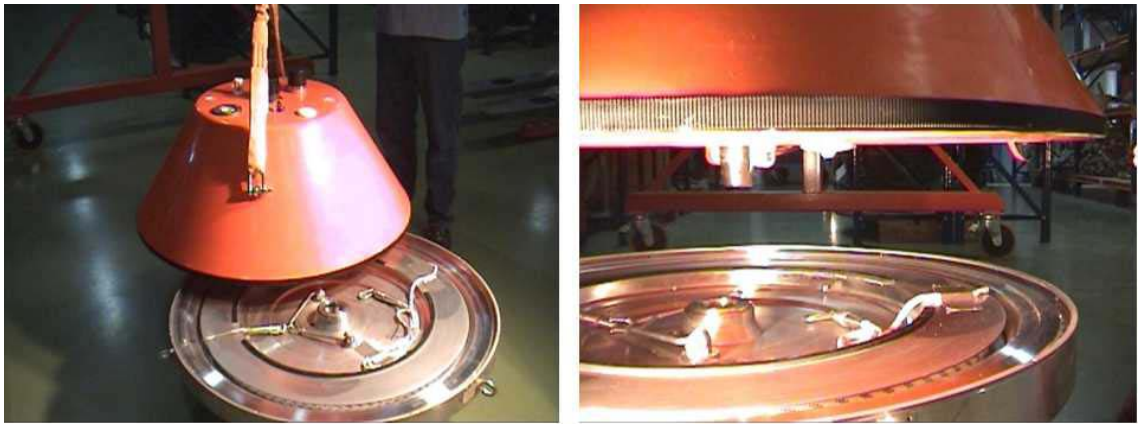

Figure 4. Low profile mine modules: 'A' (upper orange part) and 'B' (lower part)

3.3 MINEA MOORED MINE

The moored mine is composed by a buoy and a sinker. The buoy has a strong positive buoyancy and it is attached to a sinker with a mooring rope.

The buoy has the sensors, control electronics, batteries, etc. The sinker, that has the mooring rope reel and the anchoring auxiliary systems, is used as a ballast when the mine is anchored to maintain the buoy to the configured depth. The system buoy + sinker is separated during the anchoring process: the sinker stays on the seafloor and the buoy rises until reaching the configured depth.

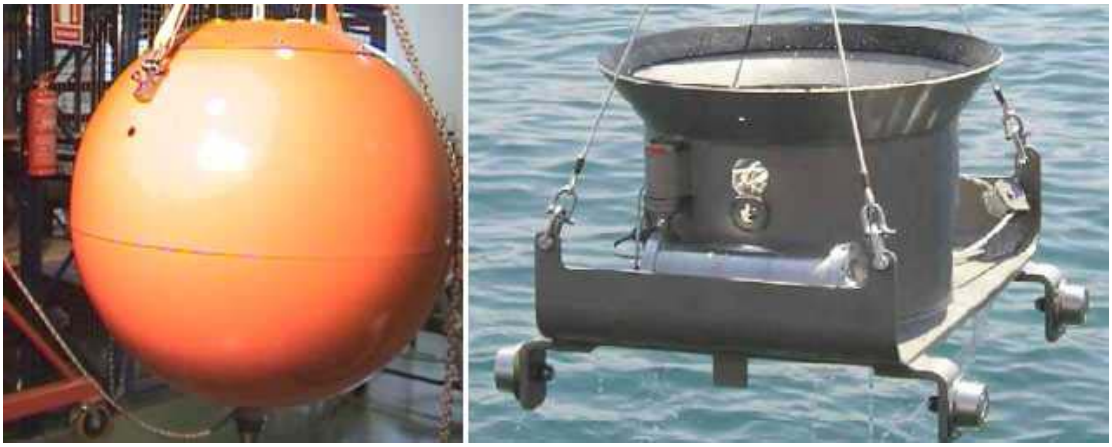

Figure 5. MINEA moored mine components: buoy (left) and sinker (right).

The moored mine has the following specific modules:

- Buoy to sinker Acoustic Link: This module communicates the buoy with the sinker when the mine is submerged. It is used to command the electro-mechanical devices of the sinker during anchoring and during recovering.
- Anchoring and Recovery System: This is a common module for anchoring and recovering. It allows the separation between the buoy and the sinker during the anchoring stage and also enables the ascent of the buoy to the surface at the recovery time.

3.4 MINEA CYLINDRICAL BOTTOM MINE

The cylindrical bottom mine is composed of two modules. The module 'A' is a watertight compartment with positive buoyancy where the sensors, control electronics, batteries, etc. are located. The module 'B' is the ballast and includes the rope reel for recovery purposes. The following figure shows both modules.

Figure 6. MINEA cylindrical bottom mine components: module 'A' (left) and module 'B' (right).

The cylindrical bottom mine has the following specific modules:

- Recovery system: Electromechanical device that enables the separation of the module 'A' at the time of recovery.
- Submarine launching supplement: This device provides the mechanical interface needed to launch the mine by submarine.

3.5 MINE SENSORS

MINEA includes the following sensors:

Magnetic sensor. This sensor detects small changes superimposed to the Earth's magnetic field. The magnetic sensor is composed by a triaxial magnetic probe and a dedicated acquisition and signal processing board. The magnetic influence is processed on the three axes, including spectral analysis.

Electric field sensor. Electric Field sensors measure electric fields or UEP ("*Underwater Electric Potential*") produced by cathodic currents in the ship or submarine hull and also from propeller or other metallic materials in contact with seawater. The sensor is composed by a triaxial array of electrodes and a dedicated acquisition and signal processing board. The electric influence is processed on the three axes, including spectral analysis.

The electrodes array is composed of SAES proprietary electrodes.

Acoustic sensor. The acoustic sensor uses an omni-directional hydrophone to detect propellers, engines, and other machinery that makes noise as the ship moves through the water. The acoustic sensor is composed by a hydrophone and a dedicated acquisition and signal processing board. Processing of the acoustic influence includes spectral analysis.

Sonar Detector. The sonar detector receives acoustic signals from the sonar of the ships. This sensor is composed by a high frequency hydrophone and a dedicated acquisition and signal processing board.

Pressure sensor. This sensor detects small pressure changes in the water caused by a passing ship near the mine. The pressure influence is characterized by a slow variation (extremely low frequency), and the used transducer is static, capable of measuring not only the small low frequency influence signal but also the large static pressure signal. Therefore, the pressure sensor is also used to measure the mine depth.

Seismic sensor (**non available on Moored Mine**). Acoustic waves can propagate in silt and rock, which comprise the seabed. In these materials, the waves are usually

understood as seismic waves and can be measured as disturbance in the particles that make up the seabed. A high sensitivity seismic transducer has been incorporated to detect the seismic influence. The seismic sensor is composed by a three-axes accelerometer and a dedicated acquisition and signal processing board.

3.6 ANECHOIC COVERING

The mines can be optionally fitted with anechoic coverings in order to reduce their sonar target strength. The coverings are detachable, very easy to be assembled or disassembled from the mines. The following figure shows anechoic coverings fitted on the mines:

Figure 7. Anechoic coverings of the mines

4 CONTROL EQUIPMENT DESCRIPTION

The Control Equipment enables the following tasks:

- To program the operating parameters.
- To command the self –test of the mine.
- To control the exercise including communication with the mine from the vessel.
- To retrieve the recorded data from the mine after the exercise.
- To replay the exercise and to analyze retrieved data.

Once the mine is submerged, it has one or more sensors activated for detecting vessels and the acoustic link open, waiting to receive commands from the Control Equipment located onboard the mother ship that controls the exercise. The programming could be changed along the exercise, through the acoustic link, using the Control Equipment.

The Control Equipment is composed by the following components:

- Central Processor.
- Global Positioning System (GPS).
- Acoustic link.
- Infrared link.
- Printer.
- Power Supply Module.

The operator interface is contained in a plastic case and includes the following components:

- Central Processor. This corresponds to a laptop computer.
- Interface with GPS.
- Interface with Acoustic Modem.
- Power Supply module.

Figure 8. Control Equipment case

The infrared link communicates the Control Equipment with the Mine in order to programme the operation parameters and recover the data from the exercises. These operations are performed out of the water. The data transfer is carried out through a high speed wireless infrared interface. An infrared probe has been specifically designed for this application in order to avoid the necessity of the Control Equipment from being close to the mine for communication.

The printer is used to obtain hard copies of the data and graphics generated through the exercise.

The Differential GPS (DGPS) unit is used to obtain and communicate the vessel position to the Control Equipment.

The acoustic link is used for bidirectional underwater data transmission between the Control Equipment and the mine. This link is established between the Control Equipment modem and the mine modem when both are submerged. These modem devices provide a very robust data transmission even in difficult environments (such as shallow waters).

5 MINE ANCHORING AND RECOVERY

5.1 BOTTOM MINES

The low profile bottom mine is launched from surface ships, whilst the cylindrical bottom mine can also be launched from a submarine. The following figures show the bottom mines launching from a surface ship.

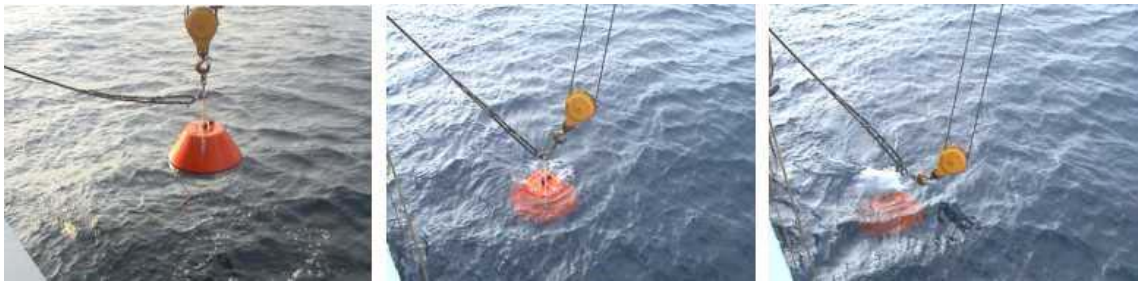

Figure 9. Low profile bottom mine launching from a surface ship

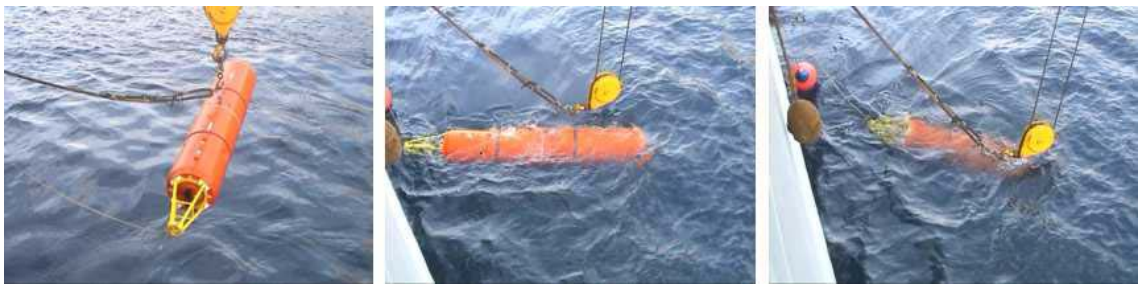

Figure 10. Cylindrical bottom mine launching from a surface ship

The mine recovery can be carried out from a surface vessel without the necessity of divers. After the recovery command (either sent to the mine through the acoustic link or programmed via a timer) the module 'A' (floating element) will rise up to the surface towing the recovery rope. The following figures show the module 'A' separation stage.

Figure 11. Low profile bottom mine module 'A' separation stage

Figure 12. Cylindrical bottom mine module 'A' separation stage

Then, the module 'A' will be recovered from the sea surface by means of a crane.

Figure 13. Module 'A' recovery stage: Low profile mine (left) and Cylindrical mine (right)

The module 'B' (ballast) will be recovered from the sea bottom by means of the recovery rope.

Figure 14. Module 'B' recovery stage: Low profile mine (left) and Cylindrical mine (right)

5.2 MOORED MINE

The moored mine will be launched from surface vessels. The launching can be performed from rails according to the STANAG 1020 through the sinker wheels. Also, the launching can be performed by means of a crane using a specific launching tool.

Figure 15. Moored mine launching from a surface ship using a specific launching tool

Once in the bottom, the buoy will rise up to the programmed depth, where it will remain anchored.

The mine recovery can be carried out from a surface vessel without the necessity of divers. After the recovery command (either sent to the mine through the acoustic link or programmed via a timer) the buoy will rise up to the surface, from where it will be recovered. The following figure shows the moored mine buoy recovery stage.

Figure 16. Moored mine buoy recovery stage

The sinker will be recovered fro the sea bottom by means of the mooring rope.

6 ENVIROMENTAL TESTS

The three types of mines have successfully passed the following environmental tests:

- Temperature tests (storage and operation) according to MIL-STD-810F.
- Shock and vibration tests according to MIL-STD-810F and MIL-STD-167.
- Electromagnetic compatibility tests according to MIL-STD-461E.
- Watertightness tests.

Figure 17. Vibration tests: Low Profile mine (left) and Cylindrical mine (right)

7 SEA TRIALS

Extensive sea trials have been performed in order to validate the design and to check the full performances of the mines. The sea trials have been carried out in two stages:

- Harbour trials: It have been performed numerous trials at harbour, close to the SAES facilities.
- Sea trials, performed in close cooperation with the Spanish Navy, which have contributed with full human and material resources.

Most of the pictures along this paper belong to harbour and sea trials.

8 CONCLUSIONS

MINEA is an advanced multi-influence mine designed and manufactured by SAES in close cooperation with the Spanish Navy, that has been extensively tested at sea showing a high level of performances in different environmental conditions. It includes a wide range of sensors (electric, magnetic, acoustic, seismic, pressure and sonar detector) and sophisticated mine logic algorithms. Three different types of mines have been developed to adapt to different operational conditions: cylindrical bottom mine, low profile bottom mine and moored mine. The use of state-of-the-art both COTS and own developed components has led to one of the most advanced available multi-influence mine in the international market.