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Technology focus
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Technologies for Underwater Surveillance Systems

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सत्यमेव जयते
भारत सरकार
Government of India

अध्यक्ष, डीआरडीओ
व
सचिव, रक्षा अनुसंधान तथा विकास विभाग
Chairman, DRDO
&
Secretary, Department of Defence R&D

MESSAGE

With a vast coastline stretching across on both the sides of the country, research and development of naval systems assumes prime importance in our quest to safeguard our critical assets both onshore and offshore. Issues related to operations and surveillance in waters around us have gained importance in the recent times, due to the proliferation of submarines made quieter due to advanced stealth technologies and long endurance energy sources. Therefore, detection of a lurking submarine, both in the brown and blue waters, has become a very critical requirement. In this regards, our DRDO lab at Kochi, NPOL has successfully lived up to the expectations of the Indian Navy and delivered cutting-edge sonar systems and underwater communication systems, which adorn the surface and subsurface vessels of the Indian Navy.

Being a multi-disciplinary domain, development of sonar systems require expertise in multiple fields ranging from embedded systems signal processing, signal conditioning, oceanography, underwater transducers, mechanical engineering and materials science. This special edition of Technology Focus presents the latest developments made by DRDO in the development of key enabling technologies in the niche area of sonar systems. I am sure that this edition would serve as a reference for anyone seeking to know about the state-of-the-art technologies in sonars.

(Dr. S Christopher)

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सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

रक्षा मंत्रालय
MINISTRY OF DEFENCE
रक्षा अनुसंधान तथा विकास संगठन
DEFENCE RESEARCH & DEVELOPMENT ORGANISATION

MESSAGE

Sonar system design involves highly complex technologies, privy to only a handful of nations in the world today. Over the years, NPOL has built up core competence in this niche area, helping the country attain self-reliance in this critical technology domain. Today, all the three dimensions of the Indian Navy, viz. the submarines, the ships and the helicopters have sonars and sonobuoy systems developed by DRDO. Unlike other sensor systems such as radars, sonars have to face the vagaries of the dynamic ocean conditions. Sonars are also highly mission critical systems. Hence, sonar systems have to be developed incorporating a high amount of reliability and maintainability, in addition to the intrinsic design requirements calling for operation in harsh marine environments. The ocean medium is also a highly noisy environment leading to poor signal to noise ratio. Further, acoustic propagation is highly complex and dependent on the ocean conditions. This has resulted in more intensified research on developing newer and better technologies for superior sonars.

This edition of Technology Focus showcases the efforts undertaken in the recent past by NPOL in developing state-of-the-art technologies for sonar systems. Some of the technologies mentioned in this edition have already found their way into systems inducted on naval platforms. I am sure that readers will be enthused to learn about the 'technologies behind-the-scene' in the making of sonar systems.

(Dr. S C Sati)

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From the Desk of Guest Editor

The Naval Physical & Oceanographic Laboratory (NPOL), Kochi was founded as Indian Naval Physical Laboratory (INPL) as part of the Indian Navy in 1952. INPL was absorbed into DRDO when the Organisation was formed in 1958 and renamed as NPOL in 1968. For most of these formative years, the laboratory was engaged in fleet support activities such as finding solutions for the reliability and maintenance issues of the imported equipment onboard the Indian naval platforms, import substitution of component/small gadgets and exploratory study/research in acoustics, transducers, oceanography, etc. From such humble beginnings, the laboratory has today evolved into a premier systems laboratory of the DRDO with a successful track record of developing and delivering multiple generations of sonar systems for all three dimensions of the Naval fleet, namely surface ships, submarines, and aircraft.

Sonar systems are the eyes and ears of submarines and also the only means of underwater detection for surface ships also. There is a perpetual race going on between stealth technologies which aim to make underwater vehicles more and more silent and stealthy in order to avoid detection by sonars and evolution of sonar technologies to make more and more powerful sonars capable of detecting the most silent submarines. This implies that sonar designers have to be perpetually in an R&D mode to design better and better sonar systems.

Designing of sonar systems is a highly multi-disciplinary enterprise calling for strong competencies in disciplines ranging from electro-acoustic transducers, special materials, underwater acoustic propagation, oceanography, signal processing, electronics, embedded systems, mechanical engineering, and systems engineering. It also calls for specialised fabrication, test and evaluation facilities. It is a tribute to the vision of the leadership and the hard work of generations of scientists and staff of the laboratory that they have successfully developed these competencies indigenously, almost from scratch to world standards.

The secret of NPOL's success lies in continuous effort to stay ahead. Today, it has joined a select club of a handful of R&D institutions in the world who can claim to have mastered the art of designing from scratch a variety of underwater surveillance and communication systems for various platforms. Earlier special issues of *Technology Focus* have covered sonar technologies developed by NPOL from a more basic perspective. This special issue aims to present some of the recent developments in the area of sonar technologies in NPOL. It is hoped that this will provide the readers a cursory insight into the challenges and complexities involved in the development of such technologies and systems.

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TECHNOLOGIES FOR UNDERWATER SURVEILLANCE SYSTEMS

A systematic study of acoustic propagation in the underwater realm has led to remarkable advances in sonar technology. This issue of *Technology Focus* on 'Technologies for Underwater Surveillance Systems' intends to give a broad overview of the advances in sonar technology that resulted from the indigenous research efforts. Advances in sonar transducer technology, sonar power amplifiers, sonar signal processing, information and display processing capabilities, sonar deployment technology integrated with new materials for vibration isolation has taken a leap forward in realising the products for end applications. Sonar system design adapts these latest technologies developed to meet user requirements. These technologies developed are judiciously used for engineering a sonar system to be installed and operated onboard surface ship, submarine, and airborne platform under the harsh marine environment.

Sonar Transducer Technology

Underwater acoustic transducers are often being referred to as the eyes and ears of sonar. The design of transducers is of critical importance in ensuring superior and reliable performance of the sonar. Acoustic transducers are mainly of two types—projectors for generation of underwater sound and hydrophones for reception of underwater sound. Several underwater acoustic transducers which would be required in the sonar projects to be undertaken by Naval Physical & Oceanographic Laboratory (NPOL), DRDO in later years were designed and developed.

Projectors

Low Frequency Flextensional Transducers and Arrays

Flextensional Transducers (FTs) are light-weight, low frequency transducers, which are mostly used for towed array sonar applications. This consists of a shell, mostly metallic, and a driver stack, which is made of piezo-electric ceramic plates. The extensional vibrations of the driver stack are converted to flexural vibrations of the shell.

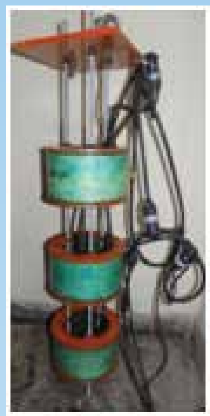
FTs resonating at 3 kHz had been developed earlier. Similar methods were adopted to design FTs of lower frequencies. FT Arrays of different configurations were developed and used in the sea trials of Towed Array System.

FTs and Two Different Configurations of FT Arrays

Free-flooded Cylindrical Transducer

Free-flooded transducers are compact, omni-directional, and high power transducers having infinite depth capability. These are ideal candidates for use in helicopter-borne dunking sonars. These are made from piezoceramic material in cylindrical form. To achieve higher source levels, cylinders are made by precisely joining several segments instead of using a monolithic piezoceramic tube.

Finite Element Modelling (FEM) studies were carried out on various options possible for the segmented cylinder and its arrays and the final designs were evolved.

Segmented Cylinder Transducer and a Prototype Array

Low Frequency Tonpilz Transducer

Tonpilz is one of the most popular and oftenly used design for underwater transducers. At low frequencies, Tonpilz becomes prohibitively voluminous, therefore Tonpilz is not generally recommended for use below 3 kHz. However, for certain special applications, low frequency Tonpilz transducers can be developed, making some deviations from standard practices. Low frequency Tonpilz transducer for shipborne cylindrical array application was developed. By adjusting the mass ratio in the design and by inserting the tail mass into the inner space of the Lead Zirconate Titanate (PZT) stack, the total dimensions of the transducer was kept within limits. Total weight of the transducer in air is 50 kg. Other features are high source level, low impedance, and directional radiation. Prototypes handled 700 watts electrical power and generated a source level of more than 200 dB ref µPa at resonance.

Low Frequency Transducer in Tonpilz Design

Piezocomposite Arrays for High Frequency Sonars

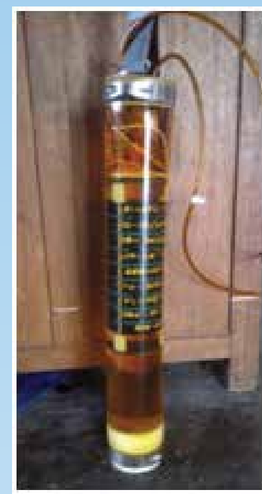
1-3 Piezocomposite transducer arrays operating in the band 70-160 kHz have been designed and developed. Two types of arrays were developed, one in a planar configuration and the other in a cylindrical configuration. The planar configuration was used in the preliminary experiments on diver detection sonar, whereas the cylindrical one was used for the development of a portable diver detection sonar.

Cylindrical Piezocomposite Transducers (Projector and Sensor Arrays) Assembled with the Electronic Unit

Directional FTs for Active Towed Array

FTs are inherently omnidirectional, by virtue of their shape and modes of vibration. Traditionally, they have been used in applications that require a nearly omnidirectional sound radiation pattern. However, in towed array applications, a source that can be operated in both omnidirectional and directional modes provides advantages because it can be used to resolve the left-right ambiguity. One of the means of achieving this by modifying the piezoceramic driver stack into a double-layer and excite them with pre-determined phase differences. Directional FTs have been developed and a prototype array has been assembled and evaluated.

Array of Low Frequency Directional Flextensional Transducers



A Module of nine Flexural Disc Projectors inside a Test Fixture

Flexural Disc Projectors for Horizontal Projector Array—Modular Projector System

Modular Projector System (MPS) is a relatively new concept, being applied by transducer designers to make low frequency acoustic projector systems making use of transducers that individually resonate at higher frequencies. Advantage of this configuration is the compactness of the projector (low frequency sound projectors are otherwise bigger, both in mass and volume).

An MPS module consists of a few high frequency projectors positioned at milli-λ spacing. The acoustic interaction among the transducer results in low frequency resonance for the module. Individual transducers in the module are Flexural Disc Projectors (FDP).

Barrel Stave Projectors

Barrel stave projectors belong to the family of flextensional transducers and are categorised under the Class I configuration. Class I FT is a compact, low frequency, high power, and omnidirectional transducer. Barrel stave transducers were developed for use in Horizontal Projector Arrays (HPA), which significantly simplifies the handling systems for deployment and recovery of towed array compared to a Vertical Project Array (VPA).

Barrel Stave Projector

Barrel Stave Array

Hydrophones

Directional Hydrophones with Multi-electroded Radially Polarised Cylinder for Towed Arrays

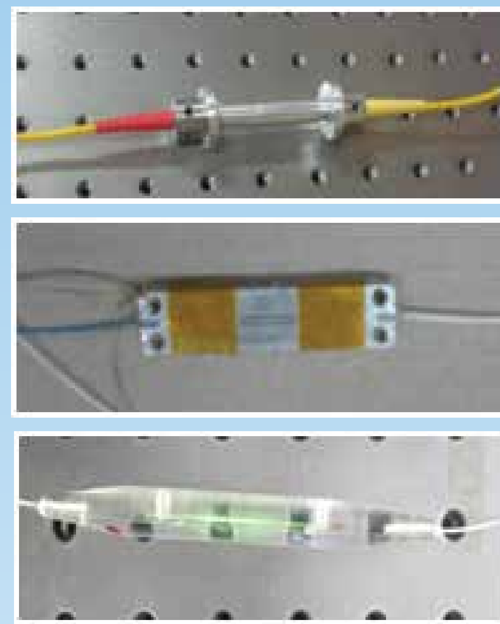
A multi-electrode compact hydrophone that can be fitted inside a 70 mm tube was designed and developed. The advantage of Multi-electroded Radially Polarised Cylinder (MERPC) is that a single hydrophone can be used for left-right ambiguity resolution in towed arrays, in place of the triplets. Hydrophone primarily comprised of a radially polarised piezoceramic cylinder with three pairs of electrodes.

This transducer has directional receiving beam patterns and a definite phase difference between electrodes in the received signal. The phase delay between electrodes is used for resolving the left-right ambiguity in towed arrays. The design takes care of acceleration-balancing as well, which significantly reduces the self-noise of the hydrophone.

MERPC Hydrophone

Fiber Optic Hydrophone Array

Fiber optic hydrophone is a non-PZT based method of sensing underwater acoustic signal. Three different configurations of fiber laser hydrophones were developed, viz., (i) End-cap type (ii) Bender-bar type, and (iii) Large diameter coating type. Prototype arrays were also assembled using 8 Nos. of bender-bar type hydrophones and using 5 Nos. of epoxy coated hydrophones.



Three Different Types of Fiber Optic Hydrophones

Prototype Array of Fiber Optic Hydrophones

Flexural Disc Hydrophones

M^2C measures the figure of merit of any piezoelectric hydrophone. High M^2C hydrophones, M being sensitivity and C capacitance, are generally preferred for sensing the quietest acoustic signal in the ocean environment. Probable application of these hydrophones is in towed array sonar systems. Therefore the general requirements are compactness in size, high M^2C value, and minimum acceleration sensitivity. Two different flexural disc hydrophone designs were evolved, which are suitable for different application, depending upon the overall dimensions. Design I is of larger diameter, which is approximately

Flexural disc hydrophones (Design I and II)

30 mm and design II diameter is 15 mm. Acceleration-balancing is incorporated in both the designs.

Triplet Hydrophones

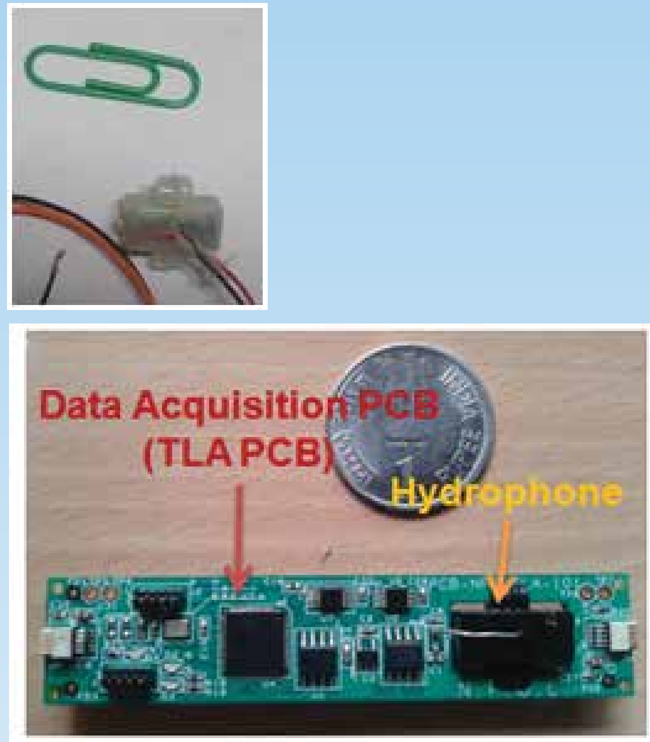
In this configuration, three hydrophones are built-in on a single piezoceramic tube, similar to the MERPCs mentioned earlier. The size and response of the hydrophones were chosen to suit the requirements of a submarine towed array sonar.

Triplet Hydrophones for Submarine Towed Arrays

Hydrophones for Thin Line Towed Arrays

Thin Line Towed Arrays (TLTA) are developed mainly for use in Autonomous Underwater Vehicles (AUVs) or Remotely Operated underwater Vehicles (ROVs). Although the concept is the same as that of the towed arrays, the technology involved is different because of its smaller size. The other important difference from all other towed systems is in the mounting scheme of hydrophones.

The hydrophone is required to be mounted directly on the data acquisition PCB. The PCB is then fitted inside an oil-filled tube of less than 20 mm inner diameter. Two configurations of hydrophones were designed, one using 1-3 piezo-composites and another using radially polarised piezoceramic cylinders.



A Single, Bare, TLTA Hydrophone and One Mounted on the PCB

Polyvinylidene Diflouride Hydrophone

Polyvinylidene Diflouride (PVDF) is a piezoelectric semicrystalline polymer which is emerging as a polymer transduction material. The polar crystalline phase imparts piezoelectricity to PVDF. The polar phase of PVDF is termed as β-PVDF and piezoelectricity is imparted through structural, mechanical, and electrical orientation of molecular dipoles. PVDF based piezoelectric polymers have low piezoelectric strain constant (d_{ij}), but, much higher piezoelectric stress constant (g_{ij}) compared to piezoelectric ceramics. The low dielectric constant, density and elastic stiffness results in the high voltage sensitivity. This high voltage sensitivity along with matching acoustic impedance with water makes

PVDF a suitable candidate for underwater acoustic sensors.

Generally employed piezoelectric ceramic materials for development of sensors and actuators for sonar applications are not suitable for large area sensor arrays that are essential for flank array and conformal array sonars. Flexibility of PVDF presents the opportunity to design a large area transducer or to shape to conform to any unconventional requirement. The flexibility of PVDF also permits design of transducers with unique radiation patterns such as an elliptical shape or with very low side lobes. PVDF polymers have a broader frequency response than piezoceramics, and are therefore not limited for use at a specific frequency. A close impedance match of PVDF with water permits efficient transduction of acoustic signals in water. PVDF also possesses required hydrostatic piezoelectric coefficients under hydrostatic pressures, thereby providing unique hydrophone performance characteristics.

Distinct advantages in using PVDF are easier hydrostatic mode design, advantage of low flow noise due to integration over a large area/extended hydrophone design, possibility of design modification by placing preamplifiers close to hydrophones facilitating use of long lengths of cable. All these advantages qualify PVDF sensor technology as one of the most suitable for use for flank array sonars for submarines. NPOL is currently engaged in design and development of PVDF based piezopolymer films and the sensor system consisting of the hydrophone and the noise and vibration isolation baffle, inhouse. A prototype hydrophone system developed exhibits a receiving sensitivity of -200 dB to -213 dB (without preamplifier) in the 500 Hz - 4 kHz band and vibration isolation of -20 to -80 dB (10 Hz to 4 kHz). Work is in progress towards fabrication of 1.0 m x 0.5 m panels comprising multiple sensors and evaluation of array performance.

PVDF Hydrophone

Staggered Cylindrical Transducer Array

Cylindrical transducer arrays are being used in shipborne sonars for active detection and tracking of submerged targets. Conventional cylindrical array follows inline configuration with transducers arranged at the corners of a square or rectangle. Many such rectangular or square cells repeat to form an array. Transducers arranged inline is often called staves. In staggered configuration, transducers are arranged at the corners of a hexagon. In staggered array, each transducer is surrounded by six primary level transducers, whereas in inline arrays, there are only four primary level neighbours. More number of

Staggered Cylindrical Transducer Array

transducers in the primary neighbourhood improves the radiation characteristics of the array. Design of staggered cylindrical transducer array is a first time effort at NPOL. Staggered array is more compact as compared to the existing inline array. The new array has more number of staves. This array offers wide frequency band and generates high source levels at all the operating frequencies.

Cables and Junction Boxes for Arrays

Cables used along with the transducer arrays have to be axially and radially tested at pressures upto 60 kg/cm^2. For distress sonar and seabed arrays, there is a requirement for cables that can withstand even greater pressures. These cables are usually imported from abroad.

DRDO has developed several underwater cables. Six different types of cables were developed. Two new types of junction boxes for use in sonar systems were also developed.

New Types of Rubber Junctions Boxes for Underwater Cables

Sonar Dome Testing at NPOL

A bow mounted sonar dome weighing 8.5 tons developed for P-15A class of warships by R&DE (Engineers), Pune and NPOL was evaluated in the acoustic tank facility. The tank has dimensions of 10.5 m × 2.2 m and 3.2 m.

The dome is made of fibre reinforced plastic composite material. This is the single largest structure ever tested in the acoustic tank. The dome was deployed in water with its acoustic centre at 3.6 m below the water surface. Acoustic waves were generated using standard projectors and hydrophones and the data acquisition and processing was done using a Pulse Measurement System. Acoustic transmission loss of the dome at various locations of the dome was measured. The dome has a baffle to isolate the own platform noise and to minimise internal reflections of the acoustic waves.

Acoustic transmission loss and reflection coefficient of the baffle was also experimentally evaluated.

Sonar Dome being Deployed in the Acoustic Tank at NPOL

Sonar Power Amplifiers

Power Amplifier (PA) is an integral part of active sonar systems which amplifies the sonar signal to the levels required by the transducer element.

A Closed Loop Power Converter Fed Power Amplifier

The power amplifiers for underwater sonar applications are generally designed to operate with 10-20 per cent duty cycle. The HT DC required for amplification of power in any sonar power amplifier system is generally bulky and are rated for continuous operation. A system with custom made AC-DC converter which is designed to operate in pulsed manner in association with a class-D power amplifier was developed. This is a closed loop processor controlled system, which has many advantages and merits over the present one.

The closed loop nature of this PA provides a highly desirable and promising feature for the sonar power amplifier technology, viz, provision of a constant power output for a designated load impedance variation. It enables the versatile programmability in qualitative and quantitative aspects. The various technical parameters such as power output, frequency, pulse length, pulse repetition rate, etc. can easily be configured.

The input AC supply variation is automatically taken care of in the AC-DC converter portion and

Dual 1kW Power Amplifier

Sonar Cabinet using 16 ň2 (and 2 spares) Nos of Power Amplifiers

output across the load is maintained constant by the feedback loop. Additional power level control is being achieved by controlling the HT DC supply also. This will enable the system to decrease the THD. In this design, provision is there to adjust the power by controlling (i) DC supply (ii) Sonar signal. It also improves the dynamic range and enables fine tuning.

This system employs phase shift modulation technique and ensures the Zero Voltage Switching (ZVS) in AC-DC converter. The ZVS provides higher efficiency by reducing switching losses and hence lesser heat dissipation. It has a novel and unique Pulse Width Modulation (PWM) generation technique at the power amplifier stage, by which the undesirable sub-harmonics can be avoided. Provision exists for ethernet connectivity and the state-of-the-art health monitoring, which is again programmable/flexible as per the customer need. Using this system, an active transmitter for upgraded version of hull mounted sonar is developed which replaces four power amplifier cabinets with a single cabinet. The existing transmitter can reduce the size significantly, with enhanced reliability, modularity, programmability, and health monitoring provisions.

Specification of 1 kW PA

Output Power	1000 W across a load from 80 Ω to 160 Ω. Adjustable in steps of 3 dB
Frequency Range	6 kHz-10 kHz
Dynamic Range	33 dB
Dimension	Height: 3U; Width:150 mm; Depth: 360 mm
Overall Efficiency	> 80 %
Input Signal	CW, LFM, HFM, and COMBO
Duty Cycle	10 % (Max pulse length: 2.58 s)

High Power Amplifier for Sonar Transmitters (8000 Wrms)

Advanced Sonar systems demands higher power transmission. This requirement is met by the new design of Sonar power amplifier with a power handling capacity of 8000 Wrms. This is a digital power amplifier using class D switching and working in full bridge topology. Two half bridge IGBT modules with solid state driver stages are used for the full bridge operation.

This PA is a rugged metallic module of 6U height, 135 mm width, and 360 mm depth and occupies only 1/5th volume of an equivalent linear amplifier. The unipolar PWM switching configuration adopted in this amplifier reduces total harmonic distortion drastically. Full bridge topology at the output stage, absorbs energy kicked back from the reactive load towards the amplifier and thereby safeguards the amplifier and power supply. The PA is equipped with short circuit, overload, and over temperature protection. Work on 300 v DC with an efficiency of > 85 per cent at full load and weighs only 12.5 kg. Transmit power level can be controlled precisely. It require only forced air cooling. The amplifier can be operated with maximum pulse duration of 1 s with a duty cycle of 10 per cent. Modular approach adopted in the amplifier design makes trouble shooting easier. Typical applications include active power amplifier for towed array, dunking and submarine sonars.

PWM based Full Bridge 8000 Wrms PA

Sonar Signal, Information and Display Processing

Sonar signal processing and Human Machine Interface (HMI) extracts information from the data received by the sensors.

ANUPAM Sonar Display Console

ANUPAM is a state-of-the-art sonar display console designed taking into account aesthetic and ergonomic considerations besides the sonar operating environment, reliability, maintainability, and environmental considerations. It is designed to enable the users to operate the sonar system for long hours without fatigue. The advanced HMI features incorporated in the design enhances the usability and effectiveness of the sonar system. Separation of the signal processing hardware from the console reduces heat dissipation and machine noise resulting in better working ambience

ANUPAM

for the operators in the sonar room and hence improves audio detection capability of the human operator. This sleek and rugged console meets the stringent environmental requirements specified for naval systems. ANUPAM designed and developed by NPOL (with design consultancy from National Institute of Design, Ahmedabad).

Features

- Aesthetic and ergonomic design
- Supports wall mounting/floor mounting/desktop mounting
- Compact dimensions to suit space constrained platforms
- Rugged design to meet JSS 55555 environmental specifications
- Panel PCs to host GUI software
- Rugged LCD panels with enhanced display resolution
- Touch input device to display configuration menu
- Support for audio-video recording
- Managed L3 Gigabit ethernet switches for connectivity
- High fidelity speakers and headphone for dual audio channels
- Utilities for operator—lamp, writing pad, document holder, document reading lamp, etc.

Specifications

Dimensions	499 mm (W) x 1843 mm (H) x 810 mm (D) [floor mount] 499 mm (W) x 1273 mm (H) x 810 mm (D) [wall mount]
Display Panel PC	20.1" panel PC with Intel processor resolution 1600 x 1200
Touch Input Device	10" resistive touch panel with Intel processor
Ethernet Switch	Managed level-3 ethernet switch
AV Recorder	Compact audio-video recorder
Audio	Compact dual speakers and headphone
Indicator Panel	Torpedo alarm, critical error, over temperature
Connectivity	MIL 38999 connectors for ethernet, USB, and power
Power Input	230 v 50 Hz AC
Ruggedisation	Meets JSS 55555 requirements

Octal Tiger SHARC VME-VXS Board

The NPLTSBF201561 is an Octal Tiger SHARC 6U VME-VXS convection cooled DSP board. Cluster of eight Tiger Sharc DSP's work as the processing engine delivering a peak performance of 24 Giga flops. A dual core BlackFin processor with a rich set of open standard interfaces (2GigE, VME, USB, UART.) work as the IO Engine, meeting all external interface requirements.

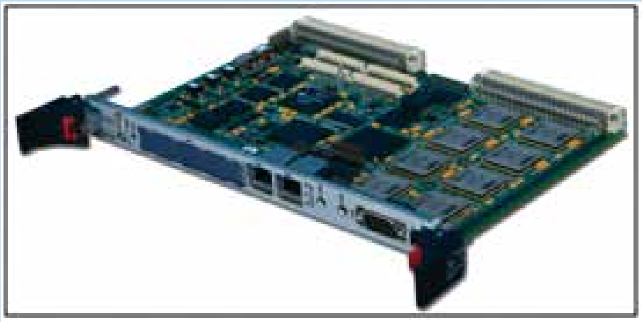
NPOL has developed an Integrated Development Environment (IDE), optimised signal processing library, board support package, and a communication management framework for enabling fast and cost-effective system design.

The PCB has a PMC slot for integrating off the shelf PMC cards. This board has computationally intensive, high bandwidth real time signal processing applications for sonar/radar.

Technical Specifications

DSP	8 x ADSP TS201 @ 500MHz, 24 Giga Flops
CPU	ADSP BF561 @ 500 MHz
Internal Memory	24 MB

External Memory	256 MB SDRAM, 128 MB NOR Flash, 2 MB DPRAM
Interfaces	2 x GigE, USB, PMC, 2 x Audio port, UART
Debug Options	3 x Temp. sensors, LED, GPIO, and JTAG
Power Consumption	35 W, convection cooled
Mechanical Dimension	6U (233.35 mm x 160 mm) VITA 41.1
Operating Temperature	- 20 to + 70 ^{0}C



Octal Tiger Sharc Board

Shallow Water Sonar Technologies—compact Electronics

An advanced integrated active-cum-passive sonar system designed for shallow water ASW platforms. It is specifically targeted for installation on smaller ships such as ASW corvettes, coastal surveillance, and patrol vessels. It employs advanced adaptive signal and information processing techniques for detection, tracking, and classification of targets. The hardware architecture is based on state-of-the-art open-architecture processor technologies that will enable smooth upgrade of the system capabilities. A compact transducer array, modular front-end signal conditioning hardware, and high efficiency switched-mode power amplifiers makes up the rest of the system.

Features

- Tailored for shallow water operations
- Built-in simulator and sensor data recorder
- Auto target designation
- Audio in both active/passive modes
- Beam tilt/stabilisation for environmental adaptability
- Automatic LRU-level FDFL
- Self-noise cancellation

Active Sonar

- Panoramic active detection, omni and directional transmission
- Waveforms-CW, LFM, SFM, COMBO and COSTAS
- Selectable pulse lengths and variable power levels
- Selectable range scales, variable fly-back, and random dwell modes
- Adaptive signal processing techniques
- Contact motion analysis and reverberation cancellation techniques
- Classification

Passive Sonar

- Automatic tracking of six passive targets
- Spectral analysis of the tracked passive targets
- Classification of passive targets
- Torpedo detection capability
- Display formats with different integration time constants

Sonar Deployment Technologies

An anti-submarine warfare operational regime demands surface ship, submarine or airborne sonars for detection, tracking, localisation, and classification of underwater targets. The deployment and retrieval of an airborne dunking sonar or surface ship towed sonar is carried out by means of sonar winches and associated underwater cables. The cables used are armored cables either electro-mechanical or electro-opto-mechanical for such applications. Airborne sonar winch for 350 m depth of operation (ASW-350), brake plates and the winch control electronics are indigenously designed and developed in collaboration with industrial partner. The tow cables form the umbilical of any towed system, improved electro-opto-mechanical tow cables namely Heavy Tow Cable (HTC) and Light Tow cable (LTC) have been developed and tested.

Airborne Sonar Winch (ASW-350)

Advanced dunking sonar applications requiring operational depths of upto 350 m require a versatile handling system for deployment and retrieval of the sonar dunk body. To perform this function, an airborne winch system ASW-350 was designed for reeling speed capabilities along with advanced features for faster, reliable, and user-friendly operations. This winch is designed using systems engineering concepts and can be configured for any operational scenario based on operator set parameters.

The winch has a modular type of mounting to suit different platforms. In addition to the vast array of functional checking sensors and safety interlock sensors, other features include the inbuilt fault detection and fault localisation module and the provision for data recording which facilitates offline analysis.

The ASW-350 winch has multiple drives and therefore calls for a gearbox with capability for multiple inputs and outputs. To achieve a lightweight gearbox, the winch employs an innovative transmission system configuration utilising planetary gears, spiral bevel gears and hypoid gears within a housing made of magnesium alloy RZ-5. This has resulted in a lightweight, but highly efficient transmission system.

Airborne Sonar Winch (ASW-350)

Some of the other innovations in the design of ASW-350 include (a) Movable heading structure for drift compensation, (b) Dual-role motor in hydraulic circuit, thereby compensating for a pump, (c) Automated operation with closed-loop control, (d) Integrated health monitoring, (e) Speed monitoring using an encoder embedded in slipring, (f) Margin in power of at least 15-20 per cent, (g) Overall weight reduction and (h) Provision for offline analysis.

Airborne Brake Plates

The airborne clutch plates were developed indigenously for use as brakes on airborne winches. The brake system in airborne winches employs a combination of friction plates and metallic plates for achieving a high level of static and dynamic braking in the wet friction condition. The friction plate has powder sintered coating over its faces, with special grooves cut over the surface.

The combination of the friction and metallic plates produces a static friction coefficient of 0.12 to 0.14 and a dynamic friction coefficient of 0.07 to 0.10.

These plates were developed indigenously by developing an alternative to 'spin-forming' technology which is unavailable in India.

Airborne Brake Plates

Test Rig for Airborne Brake Plates

A customised test rig for testing of the brake plates was also developed and the brake plates were subjected to airworthiness qualification tests approved by CEMILAC. Extensive analytical studies on strength and wear characteristics were also carried out.

Underwater Cables

Towed sonar systems require two types of tow cables namely HTC and LTC for towing the linear array and an underwater towed body behind the ship. These two cables provide the optical, electrical, and mechanical connection of the towed body and array with onboard processors. The tow cables used in the marine environment transmit power to the underwater equipment and carry signals for underwater communications. In addition, these cables are capable of withstanding the hydrodynamic forces experienced in the ocean environment due to waves, currents, or towing loads. The HTC is negatively buoyant and plays an important role in

Heavy Tow Cable

Light Tow Cable

depth keeping of towed body and rest of the array. This cable has two contra-helically wound layers of high strength Nitronic-50 alloy armour. The LTC is a neutrally buoyant cable which ensures sufficient trail or standoff distance of the towed array from the ship to limit the effects of the ship's self-noise on the array and also helps the array modules to be in the same depth as towed body. The cable employs aramid-based high strength vectran armouring. Both the cables have an overall diameter of 32 mm, terminated breaking length of 150 kN, minimum bend radius of 450 mm, and water blocking upto 50 bar.

Winch Control Electronics

The operation of airborne winch system for the deployment and retrieval of the sonar dunk body is controlled using the winch control electronics, which mainly consists of three units, viz., Winch Distribution Box (WDB), Winch Remote Control (WRC) unit, and Winch Operator Display (WOD). The winch operation is primarily controlled by a microprocessor based unit called WRC which ensures the safe operation of the winch in hydraulic mode. It is an embedded system with software running on the 32-Bit P1022 QorIQ processor. The WRC has to interact with other microprocessor based subsystems—External System Interface (ESI) of sonar system and WDB. The stave opening of the sonar dunk body is also controlled using the WRC. The WRC thus functions as the central control unit of the winch. All the commands for normal operation of the winch are initiated from this unit. The WRC software checks various pre- defined safety interlocks to ensure safe operation of the winch.

While the sonar operator interacts with the winch using the WRC, the WOD provides an option for display of the winch functioning status on the winch system itself for the winch operator. The WOD mainly consists of an AMLCD display and a QorIQ 1022 processor. The function of the processor is to provide the necessary graphical processing capabilities. The WOD is interfaced with the WRC with the help of Ethernet. It also has RS232, RS422, debugging ethernet, and USB 2.0 for debugging purposes.

WDB forms the interface to the winch system and the winch control electronics. All the sensor output from the winch and the control outputs to winch are routed through WDB. WRC and WDB are interconnected with 35 hardwired lines for routing of critical signals. There is also an ethernet link for communication between WRC and WDB to send less critical signals. The WDB is located on the winch structure.

Sonar Materials

Development of Rubber Hose for Vibration Isolation Modules

Vibration Isolation Modules (VIMs) used in towed sonar arrays. VIM attenuates the mechanical vibrations transmitted to the acoustic modules. The VIM is designed to work on energy damping principle. It consists of a damping viscoelastic

Winch Control Electronics Connected to Test Rig jelly filled inside the array tube. The module is terminated at its ends with electro-mechanical (E/M) connectors. Thermoplastic Polyurethane (TPU) hose has been in use for construction of VIM in towed arrays. However, due to limited extensibility and set problem experienced with thermoplastic elastomer during deployment of array, development of rubber based hose as alternate material is worked out. The technology to extrude rubber tubing of larger diameter and length (i.e, length more than 25 m) was not available in India.

NPOL has taken an initiative to realise the materials technology in collaboration with a suitable industrial partner. As a preliminary step, necessary rubber compound has been developed at NPOL and fabricated three variants of rubber hose (1 m) using facility at M/s. Vajra Rubber Industries, Thrissur and selected the best one based on specification requirements of VIM modules. The feasibility in fabrication of a 26 m length of tube has been established, based on the current technology developed. The developed hose was evaluated in both static and dynamic load conditions.

Rubber Hoses (1m)

Extruded NBR Plain Rubber Tube (26 m)

Development of Polyurethane Hose

Thermoplastic polymer based tubing is used as array housing for the towed/linear array sonar systems. The technology to extrude thermoplastic tubing of larger size (i.e, inner diameter more than 25 mm) was not available in India. The requirements of ongoing projects are met through import from foreign sources. Considering the strategic use of the item, these foreign sources are reluctant to supply it. Hence, NPOL has taken an initiative to indigenise the technology in collaboration with a suitable industrial partner. In a short span of time the one-to-one matched indigenous array housing of few hundred meters length was realised. The indigenous housing was subjected thorough evaluation in both static and towed conditions. Currently, PU hoses of different

Indigenous Array Housing

Indigenous Housing: 100 m Coil

diameters have been realised and the capability now exists in the country for the manufacture of PU hoses of any diameter.

Composite Acoustic Reflector

Flextensional Transducer (FT) is used extensively as high power acoustic projector for active sonar and diver deterrence applications. FTs are omni-directional in performance and it leads to loss of acoustic energy in unintended directions. By providing directionality, the performance can be improved significantly. To achieve this, a Composite Acoustic Reflector (CAR) consisting of cellular rubber core and Fibre Reinforced Plastic (FRP) casing, in a core-shell fashion developed.

The cellular rubber exhibits characteristics of excellent acoustic reflectance in underwater. The FRP shell is acoustically transparent and can withstand high hydrostatic pressure upto 15 kg/cm^3.

Two variants of the composite acoustic reflectors in parabolic shape, one for single element FT and another for 10 element FT based projector arrays were developed. Parabolic shape provides the directionality and reflective nature of cellular rubber enhances the Transmitting Voltage Response (TVR) and Source Level (SL).

Composite Acoustic Reflector

The pressure resistant FRP casing ensures consistent performance over a wide range of hydrostatic pressure upto 10 kg/cm^3. In the case of single element FT, the incorporation of composite acoustic reflector found to generate a highly directional acoustic beam with a beam width of 70°, with an enhancement of 7.8 dB in both TVR and SL was obtained. In the case of 10 element FT array, the composite acoustic reflector has enhanced the TVR and SL by 4.9 dB. The directional projector has potential applications like high power directional projectors for diver deterrence, active towed array sonar systems, as targets in sonar trials and as acoustic navigation guides.

Acoustic Lens

Acoustic lens is an attractive device for underwater imaging sonar because it uses the appropriate material that focuses a parallel wavefront of sound to an acoustic field of desired shape, focal length, and direction. Acoustic lens focuses sound in the same way that an optical lens focuses light. It is a simple way of transferring spatial information from an object to an image plane. The focusing depends on the material, number of lenses, and geometry. Lens operates at the speed of sound, form multiple beams in parallel, consumes no power.

The shape and material of the lens affects the quality of focusing. Lens forms narrow beams both on transmit and receive, resulting in two-way beam pattern generate sharper images. Lens can enhance the amplitude distribution along the sound propagating field and capable of reducing the beam width in the transverse sound pattern at the focal point. Depending on the shape of the lens, the pattern of sound energy radiated will travel along certain predictable paths. As acoustic transmission dependent on the angle of incidence and window thickness, many combinations of amplitude and phase shading are at the disposal of the designer.

The lens design is based on the beamwidth, side lobes, field of view, and focal point positions. Acoustic lens system has potentially the highest

Acoustic Lens

array gain due to large effective area of its aperture, which may translate into higher signal-to-noise ratio in the image. The effective focal distance depends on the lens geometry, refraction index, and also on the near field limit.

With acoustic lens, sonar requirements on phase and amplitude matching of the transducers are relaxed, because side-lobes and resolution are determined primarily by the lens. Mechanical focus allows sharp images over the range of interest and under different water conditions.

Acoustic lens can function as a beamformer; it forms a set of effective horizontal beams by steering sound coming from particular directions. This reduces the electronic beam forming, reduces the sampling rate and consumes less electrical power. It provides an advantageous option to amplify high frequency sound signals so that the preamplifier noise can be reduced manifold.

For underwater sound focusing, acoustic lenses of various geometries-plano concave, elliptic, double concave, and double convex with spherical and cylindrical apertures were developed. A multi-element acoustic lens system with cylindrical aperture is developed by the combination of plano concave and double concave lenses, which focus sound on a linear transducer array shows 12 dB amplification at 500 kHz.

Wireless Mode Temperature Sensor Array

Cochin estuary also one of the strategic location in the west coast of India. Prediction of sonar sound profile in this area is quite complex due to highly dynamic and complex nature of water current.

Normally, sound velocity in ocean is indirectly estimated from the salinity–temperature–depth profile of that region, measured by Conductivity-Temperature-Depth (CTD) data logger. A real time CTD profile of Cochin estuary for many seasons is not available due to logistics and heavy traffic of fishing vessels/boats, etc. In this context, a temperature sensor array (12 m long) with wireless data logger is developed inhouse which can log the temperature data of Cochin estuary upto a depth of 12 m and transmit the data to the lab in real time.

A string of polyurethane/rubber encapsulated 12 RTD/thermistor sensor temperature array is developed to monitor the temperature profile of 12m depth estuary. The thin film temeprature sensors, PT-100 and PT-10, with an accuracy ± 0.01° C are developed inhouse. The datalogger records the data from the sensors and transmits by wireless communication, either GSM or ZigBee mode. Six

String of Polyurethane /Rubber Encapsulated 12 RTD/ Thermistor Sensor Temperature Array Thin Film Temeprature Sensor numbers of temperature sensor arrays with wireless data logger were succesfully tested in the laboratory and Cochin estuary.

Towed Array Technologies

Horizontal Projector Array

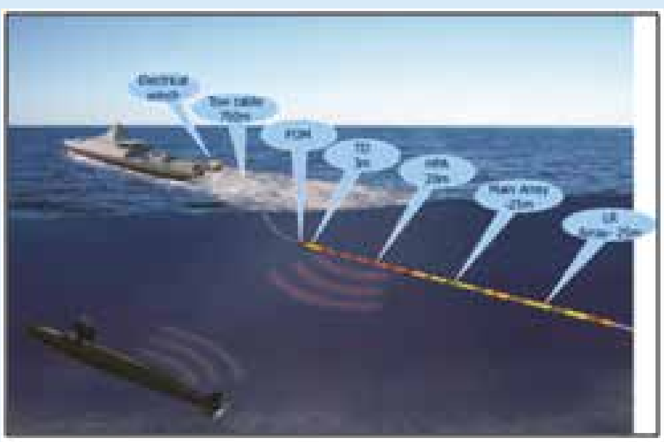
Presently, towed active sonars have a passive towed receiver array and a huge active towed projector body for transmission of high power signals. Such a system needs a complex handling system for deployment and retrieval of the transmitting body. This also places a huge constraint on the tow cable as well. If instead of a towed projector, the projectors were encapsulated in a long flexible tube, it could then be deployed and retrieved by the same mechanism as the towed receiver arrays. It would also be more reliable due to reduction in hardware and deployment complexity. NPOL is presently working to realise a prototype Horizontal Projector Array (HPA).

Power Amplifier Capsule and PCBs used in HPA

Power Converter Assembly for HPA

Signal Distribution PCB for HPA

It involves incorporating projector elements, power amplifiers, tuning coils, and the data distribution system for the power amplifier inputs inside a flexible polyurethane tube of internal diameter of 104 mm. Once all the elements are encapsulated in the tube, the access to the system is limited. Hence it is required to make all these components operate reliably. The mechanical design of the system is extremely important as the array has to maintain horizontal attitude in all regimes of operation. It is due to this reason that it is called a HPA. Since the diameter of the tube is small, instead of a single high power projector, a number of medium power projectors are used in a towed projector array. Since there are multiple projectors, there have to be as many power amplifiers as well. Since there are numerous individual elements, different directional search beam patterns can be generated from the HPA which is not possible from a conventional projector. Development of an HPA would enable even a small ship to have a power active towed array system thus improving its lethality in the operational scenario.



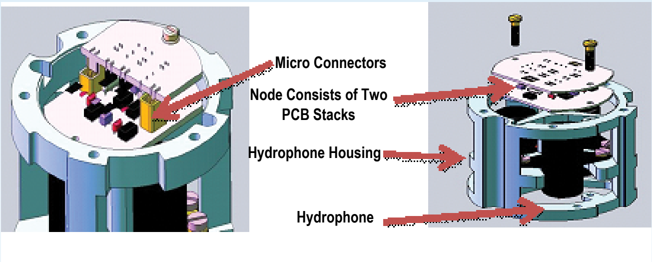
Active Towed Array Sonar with HPA

Triplet Node

Triplet node PCB is a data acquisition system for triplet hydrophones which takes advantage of miniaturised components, reduction in wiring density and standard interfaces. Each node is capable of handling the conditioning, digitisation, and conversion to ethernet close to the triplet hydrophones. The advantage of this scheme is the enhancement in signal quality due to the reduction in signal integrity issues due to fewer wires inside the array. Also since all the interfaces are standard (ethernet), fewer wiring problems are expected. The data from the different nodes are multiplexed over the same bus using ethernet switches.

Since the output of this device is in ethernet format, it can be directly fed to the signal processing module which is capable of directly receiving the ethernet packets. The scheme is achieved using two circular PCBs having 40 mm diameter stacked one above the other. The first PCB does the pre-amplification and the conditioning of signals from three hydrophones. It also includes an accelerometer-cum-magnetometer sensor for roll and heading measurement. The second PCB which is stacked with the first PCB acts as a controller for the functioning of both the PCBs.

The major functions includes the ethernet conversion of the analog signals from the signal conditioning PCB (PCB1), generating synchronising signals, filter clock, PGA signals, generating signals for sampling ADCs and controls switching action. There is a three port ethernet switch which is kept on the other side of the hydrophone assembly which does the multiplexing of ethernet data from the same node and from an external node.



Triplet Node PCBs

Advanced Distress Sonar

A strategic submarine, equipped with weapons and sensors offers immense tactical superiority to the nation. As the Indian Submarine Programme evolves and grows in sync with the maritime objectives, our submarines venture far and wide, with improving combat-worthiness day by day. It is therefore, imperative to put in place crisis management plans, emergency procedures and life saving equipment onboard these potent platforms. The indigenous development of a distress sonar system is a crucial step in this direction.

Advanced Distress Sonar

Distress sonar or submarine beacon is used to indicate that a submarine is in distress and enable quick rescue and salvage. In its simplest form, it is designed to transmit SoS signals of pre-designated frequency and pulse shape in an emergency situation while submerged, so as to attract the attention of a search and rescue vessel or submarines in the vicinity. The system has a long endurance and can transmit signals more than 90 days in distress condition. The system is designed in such a way that various classes of ship sonars/underwater communication systems or standard beacons can communicate with it for localisation. To achieve this new technology development, special pressure tolerant transducers, sealed underwater enclosures, compact high power batteries, hybrid pressure tight power over ethernet cables, etc. were developed and successfully used in the system.

High Frequency Sonar

High Frequency (HF) sonar utilises the concept of piezo composite arrays operating at high frequencies. A typical 75 KHz array can be configured for diver detection application. A portable device using the technology has been developed. HF sonar is capable of detecting potential underwater threats, like, divers and diver delivery vehicles in shallow waters. This is high frequency active sonar operating at 75 kHz. The major breakthrough was the use of piezo composite transducers for projector and receiver array. This helped in reducing the size and weight of the transducer arrays, thus making it portable. The classification of the detected targets is done and operator is alerted when a threat is identified.

The system alerts the operator to confirm the type of threat so that effective countermeasures can be initiated in time. The system can be deployed either outboard a ship or at any location in a harbour, typically beside a wall, pier or at the sea bottom. For ships the system is deployed when the ship is in harbour or anchored and is retrieved before sailing. The system consists of two parts, an underwater unit and a shore unit, interconnected by water blocked cable carrying data and power supply lines. The underwater unit is a sonar head consisting of transducer arrays, transmitter front end receiver electronics hardware. The shore unit consists of the processing and display units, data recorder, and power supply. As an auto alert system, PDDS performs detection, tracking, and classification of divers or diver-like targets automatically and alerts the operator accordingly. The target information provided by the system includes, (i) Target position (range and bearing), and (ii) Target dynamics (speed and course).

Operational Advantages

- Fully automated solution for underwater security
- Detects and classifies underwater intruders like divers with very low target strength
- Automatic alarm on detection of threat
- Capable of detecting multiple targets around 360° in the azimuthal plane
- Vertical coverage of up to 20° in elevation
- Useful for protection of waterside assets and installations with 24x7 surveillance
- Very narrow beams for fine resolution in bearing of small targets
- High probability of detection and low probability of false alarm

Cutting-edge Technology

- High frequency sonar with extended detection range
- Portable system with compact packaging
- Deployable light weight wet-end unit
- Flexible deployment schemes for fixed site applications/onboard vessels
- Marine-compliant structure housing transducer arrays and electronics
- Ruggedised system for operation in all weather and water conditions
- Modular design enables customisation for site-specific geography

Portable Diver Detection Sonar Prototype

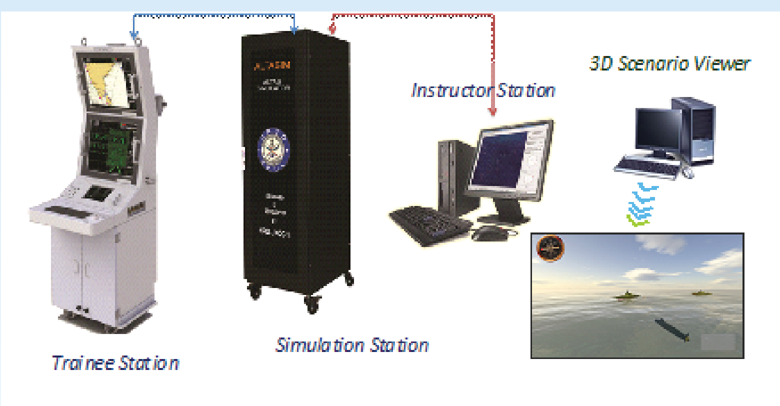
- Human Machine Interface (HMI) through rugged laptop/PC
- User-friendly GUI scheme for quick and efficient operation
- Provides sonar picture in desired formats
- Provides tactical picture GUI with map overlay
- Built in sensors for temperature, humidity, heading, tilt, and depth

Simulators and Acoustic Trainer

ALTASIM

ALTASIM is the latest Commercial off-the-shelf (COTS) based towed array sonar training platform designed and developed by NPOL to train the sonar operators of shipborne towed array sonar designed to operate at low frequencies.

ALTASIM is capable of simulating both vessel dynamics and ocean environment in which the vessels are moving. The generic signal simulator generates the signals, which closely resemble the actual signals received by arrays. The sonar signal processing is done on this data, and the audio and video outputs are presented to give a real feel of the system. Towed array sonar display controls and display formats are used to provide realistic training conditions to the operator.



ALTASIM

ALTASIM system consists of instructor station, simulation station, scenario viewer, and a trainee station. Instructor station is designed for selecting various scenarios required for training along with target and environmental parameters. Software modules required for sensor data simulation, data processing, and recording operations are incorporated inside the processor cabinet. Trainee station is designed to provide the same look and feel of sonar display cabinet and the scenario viewer will give the realistic view of the operational area in 3D.

MAARSIM

MAARSIM is the latest COTS based towed array sonar training platform designed and developed by NPOL to train the sonar operators advanced torpedo defence system. The system is capable of detecting, confusing, seducing, and decoying incoming torpedoes. A complete torpedo defence package for surface ships have been developed under this project against vintage as well as modern torpedoes.

MAARSIM is capable of simulating various tactical scenarios. The generic SNS generate the signals, which closely resemble the actual signals received by arrays. Since the signal processing is done on this data, the video and audio appears to come from a real target. Display controls and display formats are identical to the system to provide realistic training conditions to the operator.

MAARSIM system consists of instructor station, simulation station, and trainee station. These stations work under Linux operating system with additional development tools like MatLab, C++ and Qt. Instructor station is designed for selecting various scenarios required for training along with target and environmental parameters. Software modules required for sensor data simulation, data processing, and recording operations are incorporated inside the simulation station. The Simulator is installed at ASW School, Kochi.

DHWANI

Sonar systems are designed with the objective of detection, tracking, and localisation of underwater objects using acoustic energy. The principles governing the underwater acoustics are used for the design of the system. The sonar operators invariably are exposed to these principles during the training in ASW school and thereafter on the sonar system itself for the optimum utilisation itself. In that process, a gap remains unfilled in maximising the understanding of the usage of the sonar system. The gap is on account of the visualisation of the transmission of sonar energy from the ship, its propagation in sea to the target and back and the reception of this energy at the hydrophones onboard the ship. The relationships that exist among the various physical parameters and the derived parameters of the sonar needs to be better understood by the operator in the beginning itself. This acoustic trainer DHWANI is meant to bridge the above gap. With the usage of this trainer, a link is established between this theoretical understanding of sonar principles in the class and the practical training on the sonar simulator at the training school. This would enhance this visualisation of the real world with the perceived world in front of the sonar system.

DHWANI system comprises of a transparent acoustic tank with provision for positioning projectors and hydrophones, a control console, and a data acquisition unit connected to a computer. The acrylic acoustic tank (100 cm x 60 cm x 50 cm) filled with water acts as the simulated sea with targets and sonar. It has a target transportation system controlled by the DHWANI console, which permits the transmitter/projector and the hydrophone representing the receiver and the targets to be positioned at specific positions.

The active and passive targets are removable and reconfigurable with protective electronics for the safe operation of the system. Transducers with narrow beamwidth and high frequency are used in this system.The position of the target can be controlled from the DHWANI system console. The propeller noise of the target, the speed of the target, and the speed of rotation of the propeller can be controlled from DHWANI console. The system contains a projector sending transmission signals at a frequency of ~220 KHz. This can be selectively energised. The Aspect (the effective cross-section of the target as seen from the transmitted wave) can be controlled from the DHWANI console. This has an effect on the strength of the echo that is received by the receiving hydrophone. Plates are provided to mask the target in case the effect has to be demonstrated.

DHWANI control console houses two power amplifiers, a two-channel receiver with filter, and a signal generation unit. The required parameters for experiments can be set from this console. The system also includes a high-end Data Acquisition Unit (DAQ) interfaced with a computer via a USB port. The powerful PC based virtual instrumentation incorporates sonar display, conventional instrument controls for an oscilloscope, digital multimeter and an arbitrary waveform generator, etc.

The software can be run on a PC with windows XP or higher operating system.The PC is the console on which the results of the experiment can be visualised. The PC display can be configured as a function generator or as a measuring instrument with minimum hardware interconnections and it is configurable through a user-friendly menu driven software.

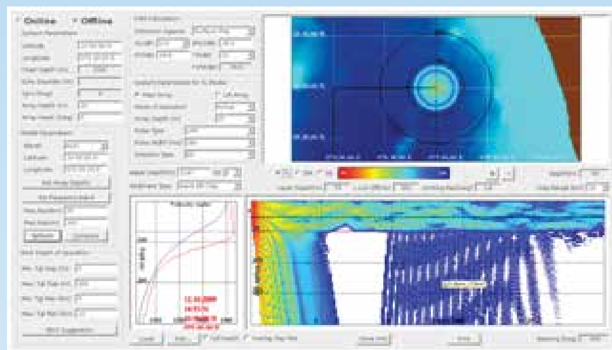
The display has two parts. One in which the signals are indicated as it may be seen on an oscilloscope. Another display is provided which represents the display as seen by a sonar operator. These two may be simultaneously correlated by the trainee for interpretation. DHWANI, as a working model, can be used for demonstration of sonar principles like passive sonar, active sonar, active sonar range resolution, transmitter and receiver beam plots, doppler, and PC based virtual instruments. The system is being used by various naval training school.

Sonar Performance and Range Prediction Technique

Sonar Performance Modeling System

Sonar Performance Modeling System (SPMS) is performance prediction software integrated to the sonar system. It is a revolutionary transformation from the existing standalone performance modeling tool and the system does not require any direct inputs. The various inputs of the model are directly received from the sonar system and from resident database.

SPMS models the Transmission Loss (TL) of the acoustic energy due to its propagation in the medium and finds the Detection Mosaic (DM) or Signal Excess (SE) against a target, based on this modeled TL for all the modes of operation of the sonar. This new software system, developed in Qt4, incorporates environmental databases (bathymetry, temperature, and salinity profiles) with a global coverage; it can be used for assessing the average performance of the sonar system in any water around the globe. It receives position (in terms of latitude and longitude) of the platform and time of operation and this information help to retrieve chart depth, temperature, and salinity profiles from the resident database thus giving a representative environment in which the sonar system operates. The integrated system also uses online estimated beam noise values for improving the performance prediction. It presents TL/detection/SE mosaics as graphical images in range-depth rectangular region or as sonar footprint (The footprint is an irregularly shaped area around a sensor where detection is possible) overlaid on bathymetry chart. It is also possible to overlay ray diagram on the range-depth TL/Detection/SE mosaic. With resident global environmental databases and interfaces with other subsystems, SPMS offers an integral and more convenient sonar performance modeling support compared to a standalone sonar Range Prediction (SRP) model. SPMS allows seamless blending of the *in-situ* temperature profile collected using the onboard XBT system with the climatological temperature and salinity profiles. This is done with the help of the resident climatological databases. The model also provides best body depth, the depth of deployment of sonar at which maximum target detection range is possible. Main window of SPMS contains different user interfaces and area for displaying graphical output. The system parameters group box in the window displays the position (in latitude and longitude), heading of the platform and sonar array depth and its heading. It also displays the chart depth taken from the database and echo-sounder depth.



Main Window of SPMS

The various parameters included in model parameters group box controls the transmission loss modeling. The modes of operation, depths of sonar for which modeling needs to be done are included in this group box. FOM calculation group box contains parameters controlling figure of merit of the system and system parameters for TL model group box controls parameters for displaying TL/DM/SE output. The output of the model in terms of transmission loss, detection, or signal excess mosaics is displayed in two areas. The polar plot at a specified depth around the sonar system is overlaid on the bathymetry chart. SPMS is now part of all the ongoing sonar projects of NPOL.

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