The Application Of Acoustic Detection Technology In The Investigation Of Submarine Pipelines

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The submarine pipeline (SP) off the southwestern coast of Taiwan was surveyed using a high-resolution sub-bottom profiler (SBP), a magnetometer, and dual-frequency side-scan sonar (SSS). One pipeline carries water with a 0.2m dia, another carries crude oil at a 1m dia, and the other three carry industrial waste water at diameters of 1.5meters, 1.7meters, and 1.8meters. In this paper, we present how well the integrated surveying system works for finding, tracking, and pinpointing submerged, aboveground, and submarine pipes. Information on the pipeline's path, its depth of burial, the make-up and structure of the sediments close to the surface, and any man-made features on or near the pipeline are all relevant to this study's overarching objective. To better suit the requirements of ocean exploitation, acoustic detection technology development will be adapted and improved. This article provides a concise overview of the acoustic detection technologies used in a variety of mission-critical marine settings, such as geophysical surveys, submarine navigation, and submarine communication.

Keywords: Acoustic detection; Submarine pipelinesurvey; Side-scan sonar and sub-bottom profiler

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1. Introduction

Oil, gas, and other commodities must be transported across great oceanic distances, and underwater pipes are essential to this process. Those pipes, which link offshore manufacturing plants to mainland processing plants or other offshore structures, are essential parts of the offshore infrastructures. Submersible pipes are vulnerable to corrosion, leakage, and reliability problems because of its subaquatic position and the severe environments that are subjected to. The conventional approaches to examine submarine pipes entail expensive and time-consuming underwater examinations carried out by dives or remotely operated vehicles (ROVs). These approaches have drawbacks in terms of availability, expense, and the effectiveness with which they may encompass huge areas. As a result, there's a growing desire for new innovations that can improve undersea pipelines detecting and tracking capacity, preserving their core values and lowering the dangers connected with failures in the future. A potentially effective method for locating undersea pipes is acoustic detecting technologies. Acoustic-based devices collect data about the state of the pipe and look for any oddities or possible issues using sound waves. It is possible to find leaks, cracks, corrosion, or any additional structural problems by examining the sounds that are sent throughout the pipes. The capability of acoustical detection equipment to cover large regions of undersea pipes absent the requirement for physical access is one of its main benefits. The sensors can be placed strategically along a pipeline's path or mounted on autonomous underwater vehicles, or AUVs, to continually gather data in real time. This makes it possible to track pipes in difficult and distant areas, increasing the operational safeguards and dependability of those systems. A non-intrusive, non-destructive examination technique is also provided by acoustic detecting technological devices.

By using sounds, it is feasible to examine the pipeline's integrity lacking actually touching it, reducing the possibility of the additional harm occurring while doing the study. This discreet strategy also lessens the requirement for costly and time-consuming maintenance tasks because routine acoustic examinations can offer useful insight into the pipeline's state of health as time goes by [1]. The capacity of mankind to use deeper water resources is continually expanding due to advances in science and technology. SP are used to move oil and gas extracted from the ocean to other sites. SP have been impacted by marine environment uncertainties for a long time, including modification in geological formations, anchoring dragging, marine corrosion, and sediment burial that have resulted in many incidences of pipeline damage and even leaking. The growth of the maritime energy sector, the healthy expansion of marine life, and the security of the marine surroundingsare all directly impacted by the safety of pipelines. Therefore, it is crucial to frequently inspect the pipes and keep them in good condition. In general, the challenging maritime environment makes it challenging to locate pipeline breaches [2].

Deep-water oil and gas resources' ability to be exploited globally is continually rising. SP are used to carry natural gas and oil that have been recovered from submarines. Subsea pipes have been impacted by marine environment uncertainties like variations in geologic construction, seawater corrosive action and sediment burial for a long period. These factors might result in pipeline damage or even leaking. As a result, periodic inspection is crucial to maintaining and ensuring the safety of SPs. The search for the discovery of leakage locations is often challenging and tough due to the convoluted nature of the maritime environment. Additionally, since the gas is continually evaporating, it is difficult to detect leakage by traces similar to oil pipes. In most cases, the working ship inspects the pipeline section by section. The daily SP inspection chores have become very labor-intensive and expensive as pipeline distance has been steadily increased. Regular SP inspection chores have become very labor-intensive and expensive with the ongoing expansion of pipeline distance [3].vA SP survey uses a variety of methods to examine and evaluate the current state of pipelines that are buried in the submarine. This kind of study is often carried out to check the integrity and safety of pipelines the fact are used to carry fluids like water, oil, gas, and other substances. To estimate the better's depth and produce an accurate representation of the submarine landscape, a lower survey uses sonar technology. This data is utilized to choose the pipeline's best path and to spot any possible dangers, such submarine impediments. Gravity-driven mass movements known as submarine landslides may be seen worldwide in a range of submarine slope situations. Therefore, an essential method for transferring sediment from the continental slope to the deep ocean is a submarine landslide and concomitant sediment density flow [4].

The globe's biggest generator of energy, the oil and gas sector is one of the greatest economic sectors worldwide. Oil and gas are moved between various locations via the extensive and intricate networks of SPs. Continuous pipeline inspection and the capacity to pinpoint the precise gas leak are particularly crucial due to the possibility of gas pipelines contaminating spills into submarine habitats. The reduction of ecological contamination, the preservation of precious energy resources, the avertance of unpleasant tragedies, and the maintenance of pipeline safety are the main goals of submarine leak detection. According to considerable study, equipment malfunctions, construction flaws, corrosion, weather, outside meddling, and harbor damage account for the majority of undersea pipeline failures [5]. Over the last ten years, the number of SP in the vicinity of Taiwan's offshore region has drastically expanded. Additionally, the Chinese Petroleum Company (CPC) specifically announced and launched a number of significant projects to build SPs. The impact of this circumstance may be deadly for the pipelines. According to a recent inquiry, the main cause of the collapse of a submarine water transport pipeline was improper pipeline inspections. To build a trustworthy process for the examination of SP near Taiwan's offshore region, theoretical and experimental research is needed. Oil, gas, and water are the principal commodities transported via SPs. The look and quality of installed pipelines are often altered by the harsh submarine environment [6].

SP are a significant means of transporting marine resources that are of considerable importance to the sustained growth of human civilization. Short SP revealed on seabed's may sustain severe damage from subsurface landslides and debris that result in resource leakage. A SP is a pipeline that is set up on the ocean bottom or buried there to move fluids like water, gas, oil, or other materials from one place to another. Several sectors, like oil and gas, mining industries, and water management, employ SPs. The diameter of a SP may vary from a few inches to several feet, and it might cover hundreds or even thousands of kilometers. The majority of the time, they are made of steel, plastic, or concrete and are made to endure the abrasive conditions of the ocean environment, such as high pressure, powerful currents, and corrosion [7]. A variety of specialized transports and types of equipment are used in the process of laying pipelines on the sea floor for SPs. The procedure begins with doing submarine survey of the seabed, followed by prepping the surface of the seabed, and ending with the laying down of the pipeline on the seabed. After the pipeline has been laid out, it is then buried in the seabed using a method known as trenching or backfilling so that it is protected from being damaged. The integrity of SPs has to be maintained at all times in order to avoid leaks, spills, and other incidents that are hazardous to both the environment and the health of people. It is required to perform routine inspections, maintenance, and repairs on SP in order to guarantee the pipelines' safe and dependable functioning. As was said in the discussion that came before this one, SP inspections are a vital component of pipeline maintenance. These inspections are necessary to identify potential problems and devise solutions for them before they escalate into serious concerns [8]. The flow of submarine of pipelines is as shown in Figure 1.

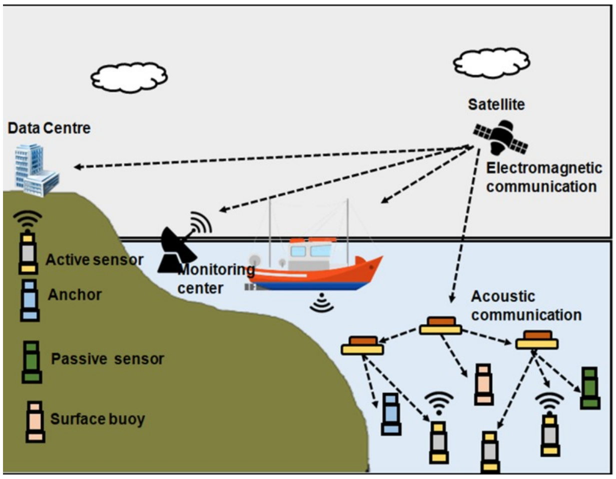

Fig. 1. Flow of submarine pipelines.

One of the most important tools in the oil and gas sector, pipelines serve a special role in the extraction and delivery of gasoline in addition to in exploring and movement of hydrocarbons. Pipelines are also one of the most common types of equipment. Since pipelines are widely regarded as the safest, most cost-effective, and environmentally responsible method of transporting petroleum, their utilization has steadily increased throughout the course of history. This is mostly attributable to the fact that pipelines provide an efficient method to raise overall energy supply. Maintaining secure, dependable, and productive offshore production facilities becomes very difficult in the event of a SP breach. Unlike pipeline leaks on the surface or in water, which are likewise quite concerning. The maritime ecosystem is constantly at danger when a SP leaks. It also results in catastrophic catastrophes that destroy assets, pollute the environment, kill people, and ruin business image [9]. The need for oil and natural gas resources has grown as science and technology have advanced. The ocean has a lot of oil and gas resources. A well-established method of transportation for the utilization of marine resources is a submarine metal pipeline. Accidents involving oil leaks are not uncommon in maritime settings, which are notoriously hostile and in which locating damage may be quite challenging. If the SP were to spring a leak, it would result in significant financial losses as well as environmental degradation; for this reason, it is very important to precisely identify any damage to the SP [10]. The effectiveness of the integrated surveying system for locating, following, and pinning down submerged, aboveground, and submarine pipelines will be discussed in this study.

2. Related works

The research [11] uses monitored data from oil pipelines and taking data from the AB-KHARK pipeline to give a corrosion analysis of the pipeline in the bursting mode utilizing a codified technique based on probability space theory. Regression and neural network machine learning indicators are used to identify the association between taking data, corrosion-affecting factors, and the lowering of pipe wall thicknesses. Based on historical information and the outcomes of statistical calculations, a novel technique is offered for simulating the failure mechanisms of offshore pipelines. The system is then looked at utilizing the first-order reliability method with accounting for the limitation state function that was established by estimating the dependability of the SP. The paper [12] provided an overview of marine sensing technologies used in certain crucial submarine situations, such as submarine inspections, navigation, and communication, as well as geological surveys. Making a trade-off between width and depth is necessary to fit as many lower-based sensors as feasible. The authors conclude by predicting the direction of submarine sensor technology development in light of the needs for future ocean exploration.

The study [13] presented a unique approach to extract pipelines that can be summed up in three phases. It is motivated by the parallels between subsurface pipes in sonar images and conspicuous items in natural images. To reduce speckle noise, a powerful denoising technique using curvelet thresholding is first suggested. The chance that a pixel refers to SP is then calculated using global information with four commonalities. Shaped similarities and angles similarity, that are suggested based on pipeline properties in sonar images, are two of them. Finally, they recommend using a fusion technique and a basic segment method utilizing bootstrapped support vector machines (SVMs) to provide accurate and complete binary segmentation findings. The paper [14] offered a review of research on some of the most recent advancements made in the investigation of SP's lateral buckling under conditions of high pressure and temperature. To better understand the actual behavior of SP, the key general hypotheses and simplifications established in the setting of pipeline lateral buckling are firstly described. Then, the pipes' governing equations for uniaxial compression are developed. The idea of an efficient axial force in a complex marine environment is then proposed, despite its controversy. The effects of initial flaws, interactions between the pipe and the seabed, and residual strains are elaborated and analyzed.

The research [15] examined on the lateral buckling of SP at high temperature and high pressure. Then, the pipeline equations of operation for uniaxial compression are developed. The idea of effective axial force in a complex submarine environment is then proposed, despite its controversy. Remaining stresses, interactions between the pipe and the seabed, and early defects are some of the influencing factors that are described and explored. The paper [16] developed a routine to semi-automatically identify the free span, condition that a pipeline segment is not supported by the seafloor, from the Synthetic Aperture Sonar images and Digital Surface Model (DSM) from an Autonomous Submarine Vehicle (AUV) hydrographic survey. The study [17] focused on the fundamentals of the technology known as Submarine Hyperspectral Imaging (UHI), and that involves a discussion of imaging devices as well as the correction techniques that are used to remove the impact of the water column. The present uses of UHI, like deep sea mineral exploitation, mapping of benthic habitats, and submarine archaeology, are discussed in this article to demonstrate the promise of this technology. This review may serve as a reference for all that are looking for literature on UHI technology and can give an introduction as well as an overview to individuals that are already working in the topic. The paper [18] presented a revolutionary Unmanned Surface Vessel (USV) architecture for the self-directed detection and identification of submerged SP. Autonomous pipeline detection and navigation system, an autonomous obstacle avoidance system, and a parametric SBP system were all included into the design. The inspection of quadratic functions produced by the lower dataset serves as the foundation for the pipeline identification. For precise SP detections, the employment of USVs equipped with SBP systems proves to be more beneficial and effective than the traditional approach.

The research [19] gathered by that method is acoustical images of profiles and the geography of the area above and below the pipeline path. One of the first rows of wharf piles will run into the sewage pipeline, according to the results of a buried pipeline safety evaluation we conducted for the installation of the planned wharf piles at Mawan Port in Shenzhen, China. The study [20] presented a strategy for locating leaks in undersea natural gas pipelines (UNGPs) using passive acoustic based received signal strength difference (RSSD). Simulations are used to evaluate the way the suggested strategy performs being applied to a real world UNGP. A benchmark approach based on received signal strength (RSS) methodology is used to compare the positioning inaccuracy of the suggested method. Although the leakage strength information is required by the RSS approach, it may not always be feasible to determine the leakage strength right once.

3. Materials and methods

In the present research, acoustic and magnetic sensor compartments was both placed in separate towed bodies and maintained at a constant 40-meter separation between the other. The seabed and overlying sedimentary layers were imaged acoustically using the SSS and SBP towfish system. Table 1 lists the sound pressure P and the sound pressure level SPL calculated from the acoustical fields at various diameters D.

Table 1. Sound pressure P and the sound pressure level SPL.

Leakage diameter(mm)	P(Pa)	SPL(dB)
2	34.2023	124.6605
3	54.9347	128.7763
4	74.0032	131.3644
5	93.9877	133.4408

The SSS has a frequency range of 100 kHz to 500 kHz. The acoustic output of the 205 dB continuous wave pulse SBP is maintained by a pulse repetition rate of 27/sec and 0.4 millisecond pulse duration. A very sensitive cesium magnetometer (10 Hz sample rate) was used to collect data on the magnetic intensity of the whole field. Table 1 provides a summary of the SSS properties.

Additionally, The Simrad EK-500 echo sounder equipment was used to measure the depths of the water's surface, and a DGPS 53, GARMIN internal GPS was used to give research location with accuracy of 3 meters with a probability equal to 95%, along with an acoustic short-baseline position submarine navigational system. SBP and SSS can pinpoint the location of submarine object within 6 m of accuracy. Diver-collected submarine videos and images

Table 2. Side-scan sonar characteristics.

	Side-Scan Sonar
Capability to map rocky seabed's	Fair
The Bottom is Within Reach	-
Capacity for precise vertical feature resolution	-
Total Beams	2
Total transducers	2
Position of deployment	Bottoms and sides of ships and submarines
Coverage	Two scan beams were angled up to 240 degrees away from the ship

were utilized to verify the accuracy of the acoustic images' categorization and interpretation. C-MAP digital nautical charts also helped by providing direction for the investigation in real-time. Images of the seafloor are produced by a SSS. The images are composed of points, referred to more commonly as pixels, the values of that are related to the quantity of power that is backscattered and are represented as grey levels.The morphological characteristics of the surface, the intrinsic nature of the surface itself, and the layout of the sensor's target system all have an effect on the backscattering, in decreasing order of importance. The reflection coefficient, R, for normal incidence may be defined by equation (1) the acoustic resistance, which is the product of the density, and the compressional wave velocity p. The reflection coefficient, v is a value of the intensity of the reflection.

$$R = \frac{p_2 \cdot v_2 - p_1 \cdot v_1}{p_2 \cdot v_2 + p_1 \cdot v_1} \tag{1}$$

During a metallic pipeline encased in concrete, the reflection coefficient (R) for normal incidence with regarding to marine water is around 0.68. The typical sandy sands that may be found off the coast of southwest Taiwan have a reflection coefficient of around 0.33. The characteristics of single-beam sonar are characterized in Table 1.

Therefore, an exposed pipeline that is sitting on sandy silt will provide the impression of shadows and dark linear scatters when seen via an acoustic microscope. The height of the following shadow will be determined by the distance the pipeline is stretched above the seabed as well as the height of the sonar towfish above the seafloor. The geocoded SSSimagewas further processed in order to get a thorough knowledge of the pipeline path in the region that was being explored. This processing comprised the following steps: radiometric correction that includes variable gain corrections, mosaicking, and geometric modifications like slant range to ground range.Summary of multi beam sonar characteristics is provided in Table 4.

A SBP and the reflections of the sediments are used to produce a highly accurate vertical profile of the shallow sediments on the seafloor at an angle of between 50 and 60 m. The SBP system efficiency, that involves depth of penetration and recovery or recognition of objects, depends on a number of characteristics. Faster pulse repetition rates are one of them, and this causes higher points the density in the profile. The standard of photographing small sedimentary formations is subsequently improved as a consequence of this. The resolution of the SB layers is the most important parameter for evaluating the performance of a SBP. In equation (2), you may find an expression that is often employed for the vertical resolution (Δz):

$$\Delta z = \frac{c}{2} \cdot T_c \tag{2}$$

where c $=$ speed of sound and T_c $=$ effective pulse duration that is caused by the transmitter pulse length, bottom reverberation, and directivity. The horizontal resolution, also known as Δx, may be calculated using the equation (3), which describes the size of the first Fresnel zone.

$$\Delta x \approx \sqrt{\lambda \cdot H/2} \tag{3}$$

where k = length of the wave and H = total of the water depth and the depth of penetration within the sediment. This number is independent of dimensions of the beam and is often quite a bit lower than the size of the area bounded by the beam's outline. The SBP that was used in this inquiry has a typical resolution of 60 centimeters for the vertical dimension and 2.3 meters for the horizontal dimension.Platinum thermistors are often employed as the temperature sensor in conductivity, temperature, and depth (CTD) measurements because of their excellent precision and large range of usable temperatures. The conversion of the pressure data is still required to acquire the depth measurement. Table 5 presents a comparison of the benefits and drawbacks associated with piezoresistive, capacitive, and resonant technologies for pressure sensors.

In determining the echo power for a meter-sized object that has been buried, corresponding ambient factors. Other examples of this type of object involve a boulder, a concrete block, or a pipeline. Reverberation can be described as the

Table 3. Single-beam sonar characteristics.

	Single-Beam Sonar
Ability to map irregular seafloors	No
The Bottom is Within Reach	Yes
Capacity for precise vertical feature resolution	No
Total Beams	One
Total transducers	One
Position of deployment	The bottoms of boats and submarines
Coverage	Beam's solid-angle size

Table 4. Multi-beam sonar characteristics.

	Multi-Beam Sonar
Capability to map rocky seabeds	Good
The Bottom is Within Reach	Yes
Capacity for precise vertical feature resolution	Yes
Total Beams	Two fifty six
Total transducers	One
Position of deployment	The bottoms of boats and submarines
Coverage	Up to 160 feet immediately under the ship; in theory, 320 feet with a Dual Head MBES

Table 5. CTDs employ pressure sensors.

Pressure Sensor	Advantages	disadvantages
Resonant	high accuracy, high stability, and sturdy construction	expensive and difficult to produce
Piezoresistive	Minimal size and complexity; maximum accuracy	weak durability
Capacitive	construction simplicity, accuracy, and durability	major deviation from linearity

Table 6. Categories of submarine navigations.

Classifications	Characteristics	Principles	Methods
Acoustic Navigation	Depending on beacons	time-of-flight (TOF) measurements of acoustic beacon signals for navigational purposes.	USBL,LBL, UBL
Geophysical Navigation	Depending on sensors to identify environmental features	navigational aids consisting on external environmental data	Acoustic feature identification, magnetic field mapping, and visual seafloor pictures
Inertial/dead reckoning	Increasing and unbounded position error	leverages motion sensors (accelerometers, gyroscopes) for a rough read on location	Compasses, barometers, pressure sensors, DVLs, INSs, and magnetic compasses

return of energy that originates from anything other than the item itself, and this definition encompasses surface, bottom, and volume reverberation. In order to unearth anything that has been buried, the buried object's echo intensity must be greater than the reverberation level. Point targets, also known as point source reflectors, are described as having dimensions that are so tiny that they are entirely insonified by the sonar beam.TheSBP that was used in this experiment has a horizontal resolution of roughly 2.3 meters (f = 3.5 kHz and H = 25 meters), respectively. As a result, it is reasonable to suppose that a target of one meter in size may be modeled as a point source reflector. In this scenario, the meter-sized item perpetually sends out signals in the form of hyperbolas, which are at their most distinct when the object is aligned in a straight line with the traverse. This tool might reveal the existence of underground pipelines in addition to the extent of their silt coverage.

The majority of metallic pipelines has extremely high permanent magnetization and exhibit individual anomalies for every measurement of the pipeline, i.e. anomalies at every connection owing to their independent thermal and mechanical histories. These anomalies may be attributed to the fact that metallic pipeline joints have different thermal and mechanical histories. Separate abnormalities may be seen in the pipeline components which are valves and other attachments. Furthermore, the magnetic signature of pipeline shifts in an anticlockwise direction in proportion to the square of the normal distance (r) that separates it from the magnetometer. This is in contrast to the behavior of a dipole, in which the shift is proportional to the cube of the distance. Therefore, the magnetic anomaly amplitude, denoted by the letter T, of a pipeline does not decrease much with distance and may be approximated using equation (4):

$$T = \frac{k \cdot F \cdot \pi \cdot D \cdot t}{r^2} \tag{4}$$

where k represents the magnetic susceptibility of the pipeline, F represents the strength of the earth's magnetic field, and D and t represent the diameter of the pipeline and the wall thickness, correspondingly.Remotely operated vehicles, often known as ROVs, do not have the same degree of adaptability as autonomous submarine vehicles, or AUVs, since they rely on cable linkages and trained pilots. A further consequence of this is that AUVs are far more reliant on navigation and positioning systems. When compared to ROVs, AUVs provide more flexibility and have lower operating costs. AUVs will have their submarine operations restricted not just by the length of time their batteries can last, but also by the distances they can navigate. In the next sections, the technologies of inertial navigation and dead reckoning (DR), acoustic navigation, and geophysical navigation will be presented, and Table 6 will provide a summary of these technologies.

4. Result analysis

The selection of these five offshore pipes for this research was based on an initial analysis of archival data gathered from the region surrounding Taiwan's south-western coast and the offshore area to the south of the island. Figure 2 contains the following information, which is a broad overview of these pipelines and is presented in the order of their geographic locations, moving from the north to the south:

- Chi-shui creek outflow pipeline,
- Tsao-ying outflow pipeline,
- Chung-chou outflow pipeline,
- Chinese petroleum company (CPC) crude oil transmission pipeline,
- Liu-chiu-yu water transport pipeline.
- Comparison of the corrected and uncorrected overwater point cloud

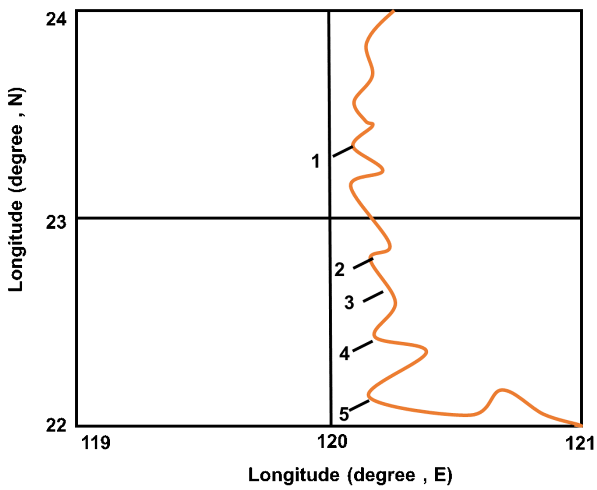

Fig. 2. Investigated pipelines' locations in geographic terms.

The pipelines were inspected in three stages using the integrated measuring technology. Every stage included a number of one-day voyages that lasted between five and seven hours. Typically, a first step was carried out to identify the general location of a pipeline. During this phase, the vessel crossed the pipeline in a 'S' pattern, making a 90-degree angle with it. With sensors placed less than 10 m above the ocean's surface, using a sound velocity of 1500 m/s, we set the ensonified range on either side of the SSS and the reported penetration depth of the SBP to 25 m.During this stage, the goal was to correctly move every pipe, and assemble data on the pipes,including whether they were proud or buried, how deep they were buried, or how high they stretched. After that, a 2ndstepwas carried out to gather data on the surficial sedimentology and manmade artifacts located close to the pipes. The survey lines were gathered in a manner that was parallel to the path that the pipeline would take. In the event that it was necessary to do so, a third step was carried out with the express purpose of collecting unique configurations of a pipeline. These included diffusers (also known as spreading outlets) that were affixed to pipes there were gravel areas that concealed pipework. The offshore survey work could only be carried out in regions with water depths of more than 10 meters because of the restrictions placed on the safety of navigation.

Images from SSS and SBP were time-aligned, and so were graphs of total magnetic intensity. Only 500 kHz SSS imagery is shown in this research due to its superior quality and greater resolution. Some of the pipes were found to have artificial concrete blocks on the seafloor, measuring one meter in size. These sections are designated for no-fishing zones and are used for anchoring navigation buoys and protecting infrastructure. Because of navigational challenges and repeated track runs, it was usual for the same block to be detected many times.

4.1. Chi-shui creek outflow pipeline

Surficial sediment samples and SSS data reveal a mostly normalto thin sand seabed with giant sand ripples in confined places around the pipeline's proposed path. Figure 3 shows how the current state of this pipeline may be broken down into three sections based on its embedding: a center buried section measuring 1330 meters in length, an east proud section measuring 280 meters in length, and a west proud segment measuring 1200 meters in length. There were nine points where the analysis path met the pipeline. At each profile, we calculated the depth of burial or the height increased over the base.

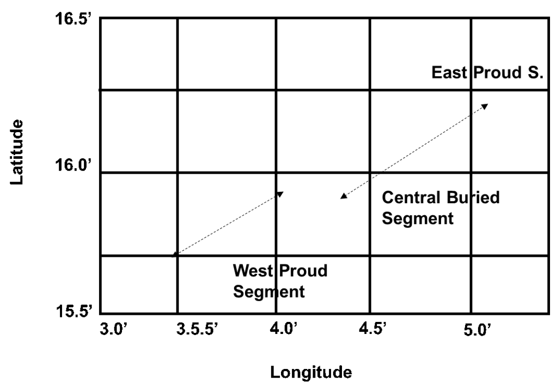

Fig. 3. Chi-shui Creek Outflow Pipeline Investigation findings.

Figure 4 depicts the most challenging section of the pipeline, which is located in the west of the country. It's made up of five prominent parts and four hidden parts. Based on SSS images, the average height of the proud section was 1 meter over the bottom. Moreover, freespans along this section of pipeline were spotted in a few places where the pipeline was higher than 1.7 mten or more freespans were found and cataloged.

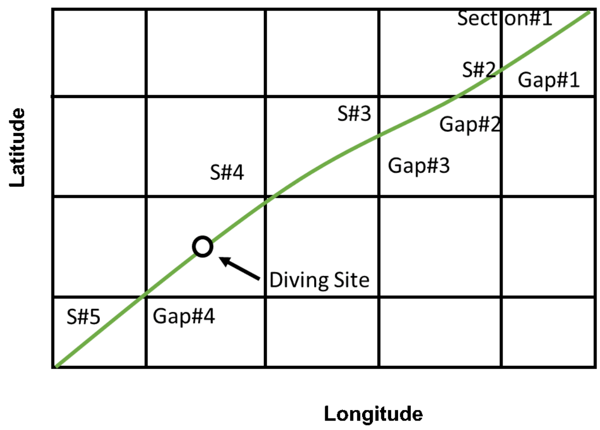

Fig. 4. West proud segment's intricate arrangements.

4.2. Tsao-ying outflow pipeline

The sedimentology of the seafloor along the pipeline's path consists mostly of normal to thin sand on a somewhat featureless, flat seabed. There were 22 points throughout the survey route when the pipeline was crossed. Figure 5 representsthe comparing data from a SSS, SBP, and magnetometer to determine the pipeline's path. The measured length of the pipeline offshore in the 250 direction is 3700 meters.

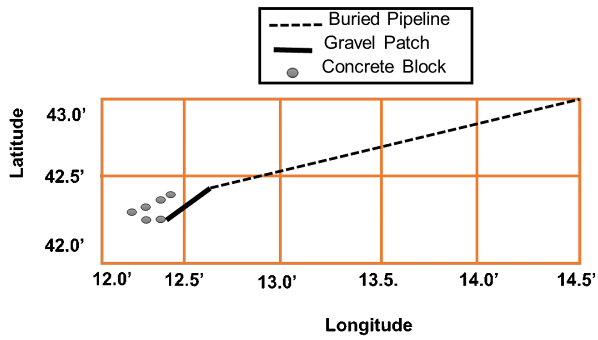

Fig. 5. Tso-ying outflow pipeline analysis results.

4.3. Chung-chou outflow pipeline

The sedimentology of the seafloor along the pipeline's path consists mostly of normal to thin sand on a relatively level seabed with areas of coarse sand spread throughout the pipeline's path. The pipeline was crossed by the survey route fourteen times. The SSSimages showed no evidence of the pipeline's acoustic footprint. However, the SBP clearly displayed hyperbola-shaped signals. Major magnetic abnormalities were also identified in total magnetic intensity vs time charts. Figure 6 shows the result of comparing data from a SSS, SBP, and magnetometer to determine the pipeline's path. The pipeline measured 2240 m in length within the investigated region and ran offshore in a 232 degree bearing.

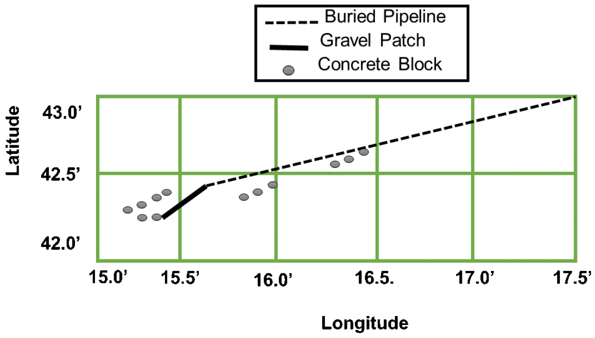

Fig. 6. Major Chung-chou outflow pipeline configurations.

4.4. CPC crude oil transmission pipeline

The area of the CPC crude oil transmission pipeline examined here has water depths ranging from 22 meters to 27 meters. The measured region has a conspicuous, constantly and diagonally distributed depression and a moderate south-westerly slope. In the western part of the examined region, the sedimentology of the seafloor is largely normal sand with linear trawlmarks dispersed throughout. The pipeline really crossed several of the trawlmarks. These man-made artifacts' origins and functions are a mystery. It was determined that the pipeline was located in a trench dug for pipeline maintenance because there were numerous large artificial objects on and around the pipeline, and because the trench was 2 meters deep and 1 meter below the average seafloor.

4.5. Liu-chiu-yu water transport pipeline

There were two field survey voyages done at this location, with the first not making use of the magnetometer. Figure 7 shows magnetic signals of the pipeline that were gathered by the magnetometer on the second voyage. However, neither the SSS nor the SBP picked up any audio signals of the pipeline on either tour. The pipeline was completely buried, as shown by the survey data, and its modest outside diameter (0.2 m) meant that its burial depth couldn'tbe established by the SBP. The anticipated pipeline path continues on a 230 degree bearing.

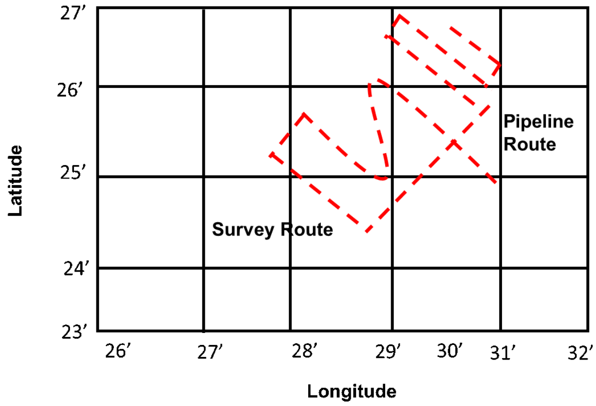

Fig. 7. Liu-chiu-yu water transport pipeline.

4.6. Comparison of the corrected and uncorrected over-water point cloud

Points mistakes were reduced by over five centimeters as a consequence of the application of correction for errors. The underground pipeline and pipelines outfalls' estimated locations have been enhanced using identical corrective factors that were used to modify the over-water cloud of points using RTK positional data. We determined the exact spot of the horizontally path of the undersea pipelines using a lowest-squares fitting technique, considering advantage of fusion information on the pipeline's underground places and the pipeline outfall position. In order to find any possible clashes among the piles and the pipes, they lastly checked the predicted pipelines pathway to the freshly built mound locations as shown in the Figure 8.

In this paper, we have taken Chi-shui creek outflow pipeline, Tsao-ying outflow pipeline, Chung-chou outflow pipeline, Chinese Petroleum Company (CPC) crude oil transmission pipeline, Liu-chiu-yu water transport pipeline as the detection technology to analyze the submarine pipelines. Technologies for acoustic detection are essential for pipelines investigations under the sea. It enables efficient oversight, detection of leaks, and upkeep of these vital networks. While using acoustic technology for detection to look for undersea pipes has many advantages, there are drawbacks as well. These involve the necessity for ongoing sensing system analysis and upkeep, noise in the background disruption, and signal attenuation over long distances. It's vital to keep in mind that the particular restrictions placed on the Chi-shui Creek discharge pipeline would depend on how it was built, what it was meant to do, and other factors. It's vital to remember that the Tsao-

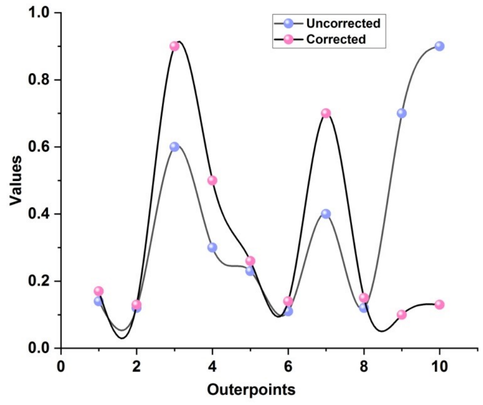

Fig. 8. Comparison of the corrected and uncorrected over-water point cloud.

ying outflow pipeline's limits will depend on how it was built, what it was designed to do, and other factors to learn precise details about this specific project. Contact the necessary authorities, project managers, or engineers working on the project to find out what the Chung-chou discharge pipeline's restrictions are. It's crucial to remember that the particular restrictions placed on CPC crude oil transmission pipelines may change depending on the pipeline's age, construction, materials, and operational circumstances. It is advised to consult the pertinent project documentation, environmental impact assessments, or get in touch with the responsible authorities or engineers involved in the pipeline's planning and construction in the Liu-chiu-yu water transport pipeline if you want accurate information about this specific project. The accuracy, completeness, and quality of the point cloud data in the presence of water are improved using these techniques, which include water surface modeling, point cloud registration, filtering algorithms, and data fusion methods.

5. Conclusion

This study provides a thorough analysis of the most common acoustic submarine detection methods. Submarine sensing systems have reaped many of the advantages of technological progress made during the last century. Rope and weight are quickly being replaced with a spectrometer as the preferred sensing instrument. Submarine pipes of varying sizes were studied with the goal of developing a reliable method for finding both exposed and hidden pipelines in the seafloor. The SSS may reveal the presence of a proud pipeline, its height, the length of a free span, the sedimentology of the seafloor near the path of the pipeline, and objects and artifacts in the surficial sediment. The SBPis used to gather information throughout the survey route. The presence of a metallic pipeline may be qualitatively determined with the use of a magnetometer. This study provided empirical evidence for the use of the multi-sensor technique as a complementary component to an engineering assessment of subsea pipes. In this paper, we have taken Chi-shui creek outflow pipeline, Tsao-ying outflow pipeline, Chung-chou outflow pipeline, Chinese Petroleum Company (CPC) crude oil transmission pipeline, Liu-chiu-yu water transport pipeline as the detection technology to analyze the submarine pipelines. Acoustic sensors must be placed, acoustic signals must be processed and analyzed, and the data must be integrated with other monitoring systems. This technology enables proactive maintenance of undersea pipelines, provides remote sensing capabilities, and improves safety through early warning systems. A major aspect of the research of underwater pipelines is acoustic detection equipment environmental interference, Background Noise, Limited Coverage, Limited Detection Capability for Some Leaks, Distance and Depth Limitations, Detection Sensitivity, Localization Accuracy.

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