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Pipeline Monitoring System by Using Wireless Sensor Network

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Abstract: *This paper describes a sensor network platform for pipeline system monitoring. Pipeline systems are widely used for distribution and transportation of petroleum, natural gas, water, and sewage. Leaks and ruptures due to an aging and fast decaying pipeline system infrastructure cost millions of dollars a year; they also make clear the necessity for continuous, automatic monitoring systems that can provide early detection and early warning of defects, such as corrosion and leaks, before they reach the magnitude of a major disaster.In this paper, we discuss how sensor networks can detect, localize, and quantify bursts, leaks and other anomalies in pipeline systems.Lamb waves are guided ultrasonic waves that can propagate for considerable distances in plates. Research has shown that it is possible to detect flaws over a large area with active sensing devices such as Lead ZirconateTitanate (PZT) for simultaneous actuation and sensing. PZT sensors can be mounted on the curve surface of the pipelines for generating and measuring guided waves that propagate along the pipes. A network of PZT actuators/sensors provide a real-time continuous and automatic monitoring of the health of the pipeline systems. Complications that encountered in Lamb wave propagation include the existence of multiple propagation modes and the dispersive nature of the modes, which makes the sensing, communication, and control a difficult task. In this paper, we will address the detection and localization problems for the proposed acoustic sensor networks using signal processing techniques. We will discuss strategies to deal with the Lamb wave dispersive propagation to achieve reasonable performance for real-time monitoring.*
Keywords: *Acoustic sensor, Lamb Wave, Wireless Sensor, Pipeline Monitoring*

I. Introduction

Oil and Gas transmission pipeline play an important role on transportation of this vital energy to the national economy. Many aging Oil, Gas pipelines suffer from various defects such as corrosion, cracks etc and can cause failure of pipeline then subsequently this may damage to human health and interruption of oil and gas supplies. For instance, on March 2, 2006, a spill of about 1 million liters of oil at around five days in the area known Alaska's North Slope because of quarter inch a hole corroded in a pipeline. This example shows the magnitude of the problem in an fast and aging decaying pipeline system.These days in order to inspect pipeline system, sensor network technologies are usable. For instance, in the applications of in the applications of natural gas pipeline inspection and monitoring by acoustic sensors [1-3].

In this paper, we reviewed the operational defects such as external corrosion, internal corrosion, fatigue, erosion, third party fatigue and fatigue. The leading cause of pipeline incidents is damage by digging near existing pipelines.The goal of our study is to investigate the feasibility of developing a continuous, remote, and real-time monitoring and inspection system using acoustic sensors that can provide early detection and early warning of defects, such as corrosion and leaks, for pipeline systems.

To achieve the goals, we reviewed rely on various acurators and sensors. There are many types of sensors that have been studied and tested for pipeline inspections including acoustic sensors, fiber magnetostrictive sensors and optic sensors. Each type of sensors has its unique feature and operational condition. In this paper, we survey the pipeline inspection technologies using acoustic sensors and describe an active acoustic sensor network platform for pipeline monitoring and inspection. We discuss basic components of the proposed sensor networks and the signal processing techniques to detect, localize, and quantify bursts, leaks and other anomalies in a pipeline system. Sensor networks technology has a wide array of applications in industry and military.

II. Monitoring of pipeline system by Lamb Wave propagation and Acoustic sensors

Sensors work with piezoelectric which occur in dielectric materials. The piezo causes physical dimension changes to electrical signals. Strain and stress generate electrical changes. The application of piezoelectric is in the field of ultrasonic transducers, sonar, resonators, electric filters, accelerometers and delay lines. In order to monitor and inspect transmission pipeline, acoustic sensors can operate in active mode or passive mode. For instance, an impact caused by a third party on a pipe wall creates acoustic waves that travel downstream and upstream in the pipeline. A passive sensor measures the timing and relative magnitude of these waves to determine the impact location and severity. However, passive sensors play minimum unctionality role and are not sufficient for pipeline inspection. Acoustic emission sensors can generate acoustic wave forms that adapt to the various pipeline operational environments to better probe the pipeline systems for defects detection and localization. In pipeline inspection, piezoelectric ceramic Lead ZirconateTitanate (PZT) based electro-mechanical impedance technique for structural health monitoring has been successfully applied to various engineering systems [4]. A PZT sensor can produce electrical charges when subjected to a strain field and conversely mechanical strain when an electric field is applied.PZT possesses the property of piezoelectricity that can be used to launch guided waves along the pipes and to measure the corresponding response time signals. However, the conventional

PZT materials are brittle and susceptible to cracking especially when the surface of the pipeline is curved. To address this issue, research has shown that flexible smart materials such as macro fiber composite sensors, shown in Figure.1, and active fiber composite sensors are the sensing and actuating devices that can adapt to the curved pipeline surfaces [1, 4].

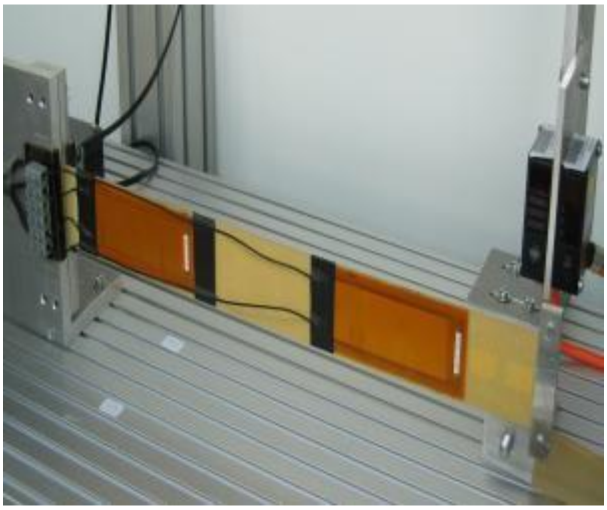

Figure1: Flexible Macro Fiber Composite (MFC) sensors

Those composite materials are composed of ceramic fibers that can bend or flex when a current is applied to them. These materials can also generate a current when they are vibrated or flexed. These unique properties provide sensing flexibility for pipeline inspection by adjusting the size and spacing of the PZT sensors and the effective configuration along the circumference. The fact that a controlled input signal can be generated and applied provides various advantages for the subsequent signal processing and damage diagnosis.
Recently, the use of Lamb waves for non-destructive testing has attracted many researchers

[5-9]. Lamb waves are guided ultrasonic waves capable of propagating relatively long distances without much attenuation in plates and laminated structures, such as airframe skins, storage tanks, and pressure vessels. This is because they are guided plane strain waves constrained by two free surfaces. The long sensing range makes Lamb waves attractive for damage inspection and diagnosis. Moreover, if a receiving sensor is positioned at a remote point on a pipe, the received signal contains information about the integrity of the line between the transmitting and receiving sensors. The test therefore monitors a line rather than a point. Hence we save considerable testing time compared with the conventional ultrasonic inspection methods where each point of a structure needs to be scanned and tested.

The propagation of Lamb waves is complicated due to their dispersive and multimode characteristics. Their propagation properties in pipelines depend on the vibration frequency as well as on the thickness and material properties of the structure. In theory, the dispersion and multimodes of Lamb waves can be described by the Rayleigh-Lamb equations for the symmetrical and anti-symmetrical modes on an infinite plate with thickness $2d$[1, 9]. Wave numbers for the longitudinal and shear modes, respectively. $\sinh(x)$ and $\cosh(x)$ are hyperbolic functions. Lamb wave behavior is described by the group and phase velocity as a function of the frequency-thickness product for a number of both symmetrical and antisymmetrical modes where each mode corresponds to a root of the Lamb wave equation [10] referred to as (S0, S1, S2, …, Sn) and (A0, A1, A2, …, An) respectively. The zero order symmetrical mode ($0S$) and the zero order anti-symmetrical mode ($0\ A$) are the most important because they exist at all frequencies. In most practical situations they carry more energy than the higher-order modes. As the frequency increases, the higher-order wave modes appear in addition to the zero-order modes.
The modes are also generally dispersive, which means that the shape of a propagating wave changes with distance along the propagation path. Lamb waves exhibit velocity dispersion,

i.e., their velocity of propagation *c* depends on the frequency (or wavelength), as well as on the elastic constants and density of the material. This phenomenon is central to the study and understanding of wave behavior in plates. There are two types of velocity dispersion forLamb wave propagation: group velocity dispersion and multimode dispersion [11]. The group velocity dispersion is caused by the frequency dependency of a single Lamb wave mode. That is, the different frequency components in a single mode travel at different speeds.As a result, the group velocity dispersion causes spreading of the wave packets. The multimode dispersion exists because different modes at a given frequency travel at different speeds. Therefore, when an input acoustic waveform with a discrete frequency is applied to a thin medium, it is separated into multiple modes that travel at different speeds. In addition, the amplitude attenuation of a Lamb wave is also frequency dependent, which results in amplitude dispersions. Hence, Lamb wave signals have complicated dispersion characteristics.

Traditionally, Lamb waves are generated in a plate or a pipe using angled contact transducers. This means that the transducers are held against the plate at an angle. Depending on the angle and the frequency, many different modes can be excited. If a plate has defects, these waves interact (e.g., reflect, scatter, etc.) with these defects; the information about the defect then can be extracted from the propagating waves.

III. Novel Caustic Sensor Network Of Detection Method For Pipeline

Effective and efficient transportation of water from utility to consumer is important as well. Investigating water losses during distribution could limit the need to access new sources of freshwater; which are already diminishing. Water losses variety in countries around the world typically range from 15 to 30 percent on average that represent a significant portion of the water supply[12, 13]. Active leak detection program is essential in identifying unidentified water leakage and losses in the delivery system. Failure at joint connections, corrosive environments, soil layer movement, loading and vibration all can contribute to pipe deterioration over time and eventual leakage [14]. Old or improper constructed type of pipelines, inadequate corrosion protection, and weak maintained valves and mechanical damage are some of the factors contributing to leakage [15]. The most commonly used method for detecting leaks in water distribution systems involves using sonic leak-detection equipment, which recognize the sound of water blow up from a pipe. The approach is based on detecting and instantaneously processing acoustic signals inside and outside pipes are widespread in leak detection. Acoustic correlation methods are more sophisticated over direct sound measurements methods where two sensors are used. The sensors in-bracket the leak and the flow time during the acoustic signals detected by the two sensors detects and locates the leak [16]. The cross-correlation method applied well in metal pipes; however, the effectiveness of the method is doubtful with both metallic and plastic pipes [17]. The motivation for experiment this technique stems from the following practical considerations:

- Ability to survey long distance pipeline in a network.
- surveying portions of the pipeline network, which may be logistically difficult to access by other techniques.
- The closeness of the sensor to the leak location.
- Leak detection and localization becomes more independent of pipe material, pipe depth, soil type, background noise, and environmental effects.

In this approach, the technique relies mainly on the sound moving through the water column inside the pipe. In order to show how the sound velocity in the pipe is directly influenced by pipe material and diameter, one may refer to the general expression for speed of sound in water-filled pipes, which was derived in [17] as;

$Vp=V0\ 1+K.dE.t$ (1)

Where *Vp*is the sound velocity in the pipe, *Vo* sound velocity in free-field water, *K* is the bulk modulus of elasticity in water, *E* is the modulus of elasticity of pipe material, *d* is the inner diameter of pipe, and *t* is the pipe wall thickness, It is demonstrate that sound velocity in water pipes depends upon, it is influenced by the pipe material or the elasticity modulus and the ratio between diameter and wall thickness. Furthermore, larger diameters and more flexible pipes tend to attenuate higher frequencies. Accordingly, low-frequency signals will be more obvious. This effect makes leak signals susceptible to interference from low-frequency vibrations, e.g., from pumps and road traffic. To explore the practical feasibility of acquiring a clean reliable signal emitted by a leak and measured from inside the pipe, experiments were conducted. The present experiments represent the first phase of an extended experimental program on developing a mobile leak detection system travelling inside the pipe. Available open literature on in-pipe sensing for leak detection do not give reliable information about the

1. Detection System

The pipeline leak acoustic emission detection system is shown in Fig. 2. A two-channel digital testing system the hydrophone is used with pressure transducer. This pressure transducer has a built-in amplifier and produces ±5V for 1 psi pressure fluctuation. It is connected to a 1-channel, line-powered, ICP® sensor signal conditioner model 482A21 which provides constant current excitation to the sensor. The hydrophone, B&K model 8103, with sensitivity 25.9 µV/Pa, is inserted into the pipe through a caped tee with sealant for data cable. The leaking valves were located 2,090 mm from the inlet pipe. Pressure gauge, rotor flow meter had been installed on the pipeline; the pipeline could be installed with sensors, and they were connected with the pc software; the values of the change of pipeline pressure and flow rate were obtained at any time.

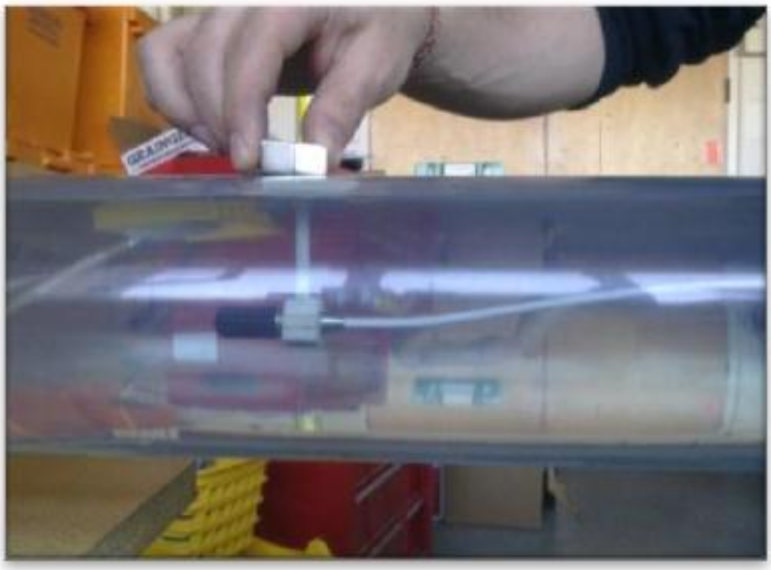

Figure 2: Pipe leak detection and localization method based on acoustic emission

IV. Discussion

The approach previously did cross-correlation method works well in metal pipes; however, the effectiveness of this case is doubtful with metallic and plastic pipes. The problems of using the present conventional correlation techniques with plastic pipes include the following: High fluctuation; this means that distances between the sensors and the type and quality of sensor are of great importance. Moreover, low frequency content; the frequency content of the leak noise is very low (<50 Hz) and therefore very hard to distinguish as a leak. Furthermore, the propagation of low frequency sound/vibration will be limited by the impedance of fittings. A method to detect pipeline features and leaks using signal processing of reflected pressure wave measurements is described. In addition, the increasing of distance led to acoustic emission signal attenuation increases too. The acoustic leak technique depend on external measurements is normally faced by some serious problems, which include greater signal attenuation in plastic pipes, greater attenuation in large diameter pipes, attenuation caused by soft soils; e.g. clay or grass, pipes buried under the water table level, and pipes with pressure less than 10 meters. Attempts to characterize leaks in pipelines by utilizing internal measurements of the acoustic signal generated by the leak were conducted using either a hydrophone. The drawback of this method is the noise gathered with wave and probably some optimization for signal (measurement) or filtering the measurement may be required

6.1 Acoustic Detection &Data Transmission:

As soon as a leak takes place in a pipeline, it creates acoustic sound waves. This acoustic signal moves along the pipeline therefore operators can detect the leakage by investigating the acoustic signal. The following paragraphs explain features of acoustic leak signal. A leak's frequency behaviors, as well as its amplitude, rely on lots of factors, for example, the size of leak, the composition of transported liquid (i.e., water, oil), and pipeline pressure. If the pipe is larger than normal in diameter or less solid, then the leak sound holds lower frequency signals and if the pressure is high, higher-frequency signals will be showing.

The amplitude of the leak sound wave is greater if the pressure or flow speed is greater or if the leak is large, but not massively large [17, 18]. If working conditions of the pipeline, for example temperature, pressure, and flow do not vary, then the leak wave is assumed to be a stationary signal, a signal that its frequency do not change as time passes. How much the signal can move also depends on many conditions like type of pipeline (i.e., PVC, iron) and the pipe's surrounding atmosphere.

A leak signal moves along the metal pipe but decreases exponentially with plastic or concrete pipe [17, 18]. When pipe is placed underground, a leak signal is decreased more than whereas the pipe is above land. The signal is decreased in lower rate in sandy soil, asphalt, and concrete but declines more in clayey or grass areas

[17]. Besides, deduction of the leak signal, while it moves along the pipe, is not linear, i.e. deduction factors of varying frequencies are different [19].

The previous leak identification technique based of acoustic discharge is very vivid: a man utilizes a gadget to hear the acoustic sound and figure out if there is a leak. The outcomes depend can be a foreordain as greatest modulus [20], Hidden Markov Machine (HMM) [20], or base on preparing values in a bolster vector machine [21], or Neural system (Jiaoet al., 2006).

These strategies have drawn backs while being complex and accurate. Among them, the Support vector machine offsets processing complexity and result precision. With just two stages, leak location results are great under experimental conditions, yet results will be less productive practically speaking. These strategies don't manage noise, and noise can make the outcome misleading. Thusly, to expand precision, we propose once again identification technique which has three stages, as in Figure below. One more stage is included before the Feature separating phase. This stage will reject noise from the leak signal. As specified in previous paragraphs, there are two sorts of noise: stationary and non-stationary. Stationary noise may be uprooted verifiably by the perceiving model. Non-stationary noise is a critical factor influencing the perceiving results. Wavelet transformation can be utilized viably to cancel out the non-stationary noise and is displayed in Daneti, 2008.

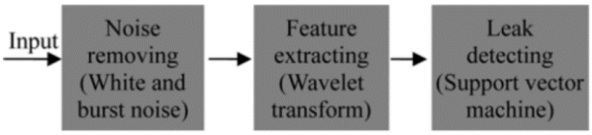

Figure 3: Identification technique in 3 stages

Later, numerous studies utilized a PC to investigate the ghostly elements of an acoustic sound to find leaks [20]. The detecting strategy in these studies by large incorporates two stages: separating signal components and perceiving the sign base on separated components. Separating signal elements intends to concentrate on specific signal attributes [17]. Separated components are utilized to show the actual signal and supplant the first signal in the following process. Leak signal shifts under different conditions, as talked about in the past paragraphs. For precise results, the framework must highlight the features and precisely recognize between leak wave and noise.

Fourier transformation is a general strategy to concentrate recurrence features of a signal and is utilized as a part of numerous applications, including an approach to concentrate leak signal components. Utilizing Linear Expectation Cepstrum Coefficients (LPCC) is another approach to concentrate on signal elements [17]. As of late, another plan, which is promising and intriguing to numerous specialists, is to utilize wavelet change coefficients to show the signal feature highlights. Compared with Fourier transformation, wavelet transformation reckoning is less and it reflects both the recurrence and timing of the signal wave, while Fourier transformation just mirrors the recurrence of the sign. Subsequent to acquiring signal components, a perceiving model uses these elements to figure out if a signal wave is a leak signal.

To locate a leak in the pipeline, we need input from two sensors with the condition that the leak must happen between two sensors, as in Figure below.

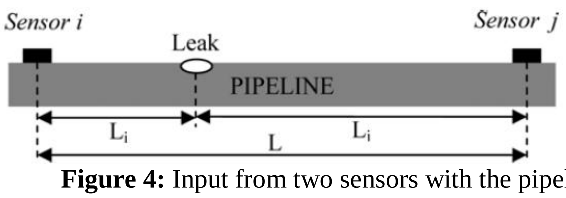

Figure 4: Input from two sensors with the pipeline

From above figure, we have:

$$L = L_i + L_j = 2L_i - (L_i - L_j)$$

As a leak happens, it propagates and reaches sensor i and sensor j at times ti and tj, respectively. Assuming that the leak signal propagation p, which can be predetermined easily, is constant along the pipe, Equation above becomes:

$$L = 2L_i - p(t_i - t_j) = 2L_i - p\Delta t_{ij}$$

leak locating requires determining Δtij. To determine Δtij, the general autocorrelation (Knapp and Carter, 1976) is often used. This method models the receive signals at two sensors as below:

$$\begin{cases} s_i(t) = l(t) + n_i(t) \\ s_j(t) = \alpha l(t + \Delta t_{ij}) + n_j(t) \end{cases}$$

withsi(t) and sj(t) as the received signals at sensor i and sensor respectively. l(t) is the leak signal, α represents signal attenuation, and ni(t) and nj(t) represent noise. With this method, noise must be a stationary signal, otherwise the leak locating result is incorrect. Other methods rejecting noise and determining Δtij concurrency are presented in Yumei et al. (2004) and Daneti(2008). When noise ni(t) and nj(t) including stationary and nonstationary waves are removed, time lag Δtij can be figured out by a cross-correlation strategy as discussed in previous sections. Firstly, the cross-correlation of two waves, si(t) and sj(t), are calculated, as in equation shown below Then, the t value that makes Rsi,sj max is calculated. This value is the time lag, Δtij.

$$R_{S_i,S_j}(t) = \int_{-\infty}^{\infty} (s_i^*(\delta).s_j(t+\delta))d\delta$$

Where si* denotes the complex conjugate of the si wave. In summary, to localize the leak, we require data signals from two sensors.

First, noise combining background and burst noise is cancelled out. Next, cross-correlation of the two sensor data is determined. Then, adding the location which make the cross correlation maximize and the sample rate, we calculate the time lag in arrival time of the two sensors. Finally, the leak point can be calculated.

In a remote sensor arrangement, a sensor hub gathers sensor information and makes connection with other hubs or nods in the framework. The most well-known sensor hub utilized as a part of over ground applications is a MICA2 board, indicated in figure below. AMICA2 board has an extension connector which associates with sensors. The focal piece of the MICA2 is an ATMega128L microcontroller that controls the sensor assembling and imparting procedures. Power is given by two AA batteries, and an extra power supply associate with an outside power connector, which just needs to interact with an antenna to impart remotely. Its fundamental transmission elements are demonstrated in Table below as well.

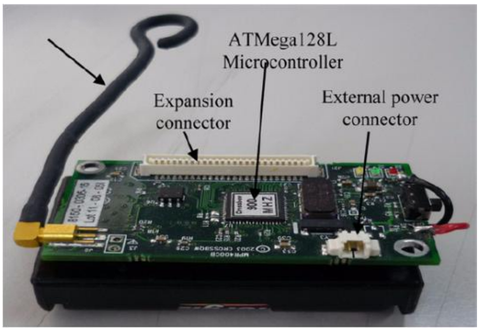

Figure 5: AMICA2 board has an extension connector which associates with sensors

MICA2 Transmission Features

Name	Value
Output gain	5 dBm
Receive sensitivity	-98 dBm
Signal rate	38.4 Kbaud
Outdoor range	150 m
Center frequency	300-915 MHz

Table 1: MICA2 fundamental transmission elements are demonstrated

With the information rate of 38.4 k Baud and an open air-range scope of 150 m, the MICA2 is suitable for most over-the-ground remote sensor system applications. Despite the fact that the MICA2 is not produced for underground applications, most current underground remote sensor systems use it. Shockingly, underground situations with diverse blends of sand, soil, dirt, and dampness are unfavorable for Electromagnetic (EM) wave transmissions which are utilized for correspondence as a part of MICA2 sheets.

A few studies display the impact of the underground environment on EM, and every one of them show that EM transmission constriction is high in underground situations [22]. Test results demonstrate that the remote correspondence separation can't surpass 7 m evenly and 0.6 m vertically for the MICA2 board (Stuntebeck et al., 2006). With these separation restrictions, MICA2 is hard to use for applications in which the sensor hubs are covered in the ground.

To build underground correspondence, other transmission systems are considered in Vasquez et al. (2004) and Sojdehei et al. (2001), however more examination is required some time recently they are pragmatic. Henceforth, at present, sensible underground correspondence is still EM; in this way, MICA2 is still the suitable determination for underground remote correspondence. This is the confinement of underground remote sensor systems at this time and it should be considered when outlining underground checking frameworks. Another issue with covered sensor hubs is the power supply. To convey underground, sensor hubs must transmit signals with higher vitality than over the ground; henceforth, they require more power. Sensor hubs are normally battery-powered, yet evolving batteries is now and again unthinkable for covered sensor hubs. The battery needs to give enough power to the sensor hub amid the whole working time. To give enough vitality to long term operations, the battery size may turn out to be too enormous to be sent with a sensor hub. One practical arrangement is to incorporate a gadget into the sensor hub that can create electrical vitality from different sources with the sensor hub [23]. This source would be an outer power supply that gives extra power to the sensor hub. Besides, picking a suitable sensor for a sensor hub is an imperative issue. There are numerous sorts of acoustic sensors such as piezoelectric or fiber gloating with diverse shapes, sizes and sensitivities. Fiber gloating sensors have numerous points of interest, such as exactness, electromagnetic insusceptibility, and cruel environment safety; however they are hard to coordinate with remote sensor hubs, which oblige low power utilization, effortlessness, and cost proficiency. With suitable components, for example, little size, light weight, and straightforward association, piezoelectric sensors are the most suitable for acoustic sensor hubs covered underground.

Piezoelectric acoustic sensors use piezoelectric impacts to transduce acoustic sound into power. The recurrence reaction of this sensor sort can change with recurrence. Distinctive sensors have contrasts in sense recurrence range. With different anticipated location leaks, recurrence reaches are diverse. Thusly, the picked sensor must have the suitable recurrence reaction. The wide band sensor can sense an expansive scope of frequencies; hence, it can distinguish numerous sorts of leak, however it makes handling more perplexing on the grounds that it additionally incorporates rich noise.

As for proposed testing field, as said in previous paragraphs, sensor hubs for underground frameworks have more issues that should be considered. Subsequently, we propose another structure for sensor hubs of leakage observing frameworks for underground pipelines shown in figure below. The acoustic sensor is a piezoelectric acoustic sensor which changes over acoustic outflows to electrical signs. A MICA2 board interfaces with the sensor, assembles sensor information, and after that wirelessly exchanges information to the next hub. Power is given by a rechargeable battery. There are combined power generators which transforms other energies to power to accommodate the operation of the sensor hub. Since this power is not steady, it can't supply power straightforwardly to the sensor hub.

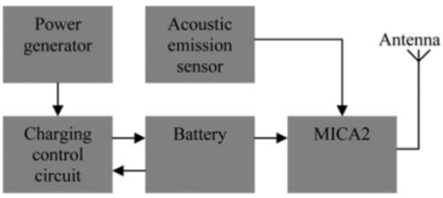

Figure 6: hubs of leakage observing frameworks for underground pipelines

The power is restored in a rechargeable battery. A battery charging control circuit controls the charging process and guarantees that the battery is most certainly not cheated. The battery and power generator guarantees that the sensor hub has enough power for its operational lifetime. In light of examination of the leak acoustic outflow handling and wireless underground sensor hub, we propose a WSN checking framework for checking underground pipeline leak, as indicated in figure below.

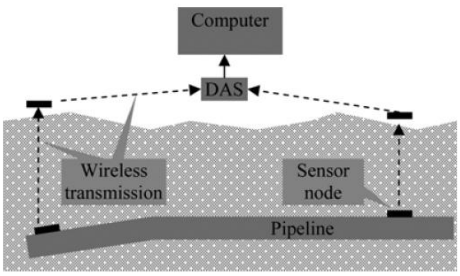

Figure 7: WSN checking framework for checking underground pipeline leak.

The framework incorporates sensor hubs that are covered underground. The sensor is mounted on a channel surface to sense acoustic outflows by changing over them to electrical signs. The MICA2 board changes over the simple electrical sign to an advanced number, includes a time stamp, stores it in glimmer memory and afterward bundles and exchanges them to another hub. Since underground wireless correspondence separation is moderately short, as said in segment III, the topology of the WSN must be composed deliberately. One MICA2 board, a wireless repeater, is put on the ground above each covered sensor hub. The MICA2 board gets bundles from underground sensor hubs. At that point, they forward these bundles to a foreordained MICA2 board, called a Data Acquiring Station (DAS). DAS gets all sensor information and afterward transmits it to a PC by a RS232 or LAN interface. At the PC, leak recognition, area, and observing procedures are performed.

The observing procedure at the PC includes numerous strides. Initially, noise in the sensor information is rejected. Next, the Wavelet transform is connected to concentrate sign components. Sign elements are the information for a Support vector machine to figure out whether a leak happened. On the off chance that there is a leak, then a leak area strategy is performed. The procedure is performed commonly, as designed by the client, to guarantee that the outcome is right. In the event that the leak results are predictable, a caution is actuated. The pseudo-code of the process in the PC is demonstrated in figure below. With the proposed system topology, the framework is anything but difficult to convey, arrange, and keep up. One DAS can gather information from sensor hubs in a range of 150 m. In the event that more noteworthy separation is required, it can be effectively come to by setting one more MICA2 sheets in the middle of DAS and the MICA2 board set over the covered sensor hub. The confinement of our proposed framework is that the profundity of the observed pipeline must be not exactly or equivalent to 0.6 m in light of the points of confinement of EM transmission in underground situations.

```
REPEAT
    OBTAIN sensors' data
    PERFORMnoise removing
    PERFORMfeatures extracting
    PERFORMleak detecting
    IF  detect leakTHEN
    DETERMINEleaklocation
    ENDIF
UNTILdetect leak
PERFORMalarming
```

The wireless network of our proposed testing stage was checked and tested by trials. Analyses were performed outside at the Myongji University grounds. The main trial was performed to focus the correspondence separation in the middle of DAS and MICA2 sheets, which were set over the ground in our proposed framework. The exploratory arrangement is represented in figure below. Two MICA2 sheets were set over the ground. One board continuously sent information parcels, while the other board distinguished the parcel. The separation between the two sheets was expanded until they couldn't impart or the parcel wasn't got.

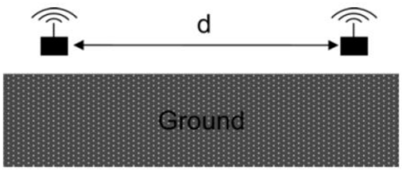

Figure 8: The exploratory arrangement is represented

Info quality was measured, while the separation was expanded figure below. Data quality diminished straightly with separation. At a separation of 10 m, information quality was under the breaking point (i.e., -95 dBm) of the MICA2 board. At distance of more than 10 m, the two devices couldn't convey and were limited. The second test was performed to focus the utmost of the correspondence separation between the MICA2 board on the ground and the MICA2 board covered underground.

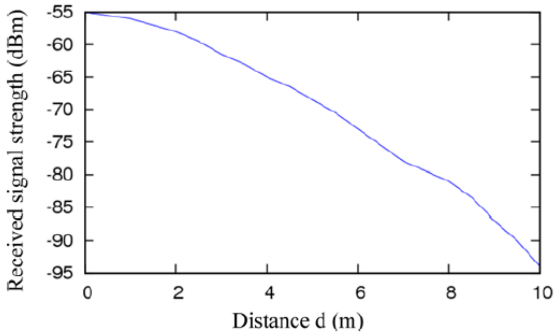

Figure 9: The experiment plan

The experiment plan is shown in figure 9. The distance between the two sensors was increased until they could not communicate.

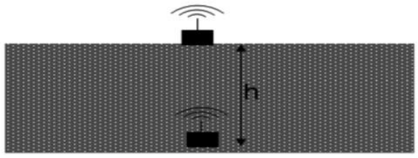

Figure 10: The distance between the two sensors was increased until they could not communicate.

The incoming signal strength was determined and shown in figure below. Reduction rate in the underground environment was much greater than in the above ground atmosphere. Incoming signal strength reduced very fast. The depth limitation of a buried sensor is 30 cm based on our real experiment.

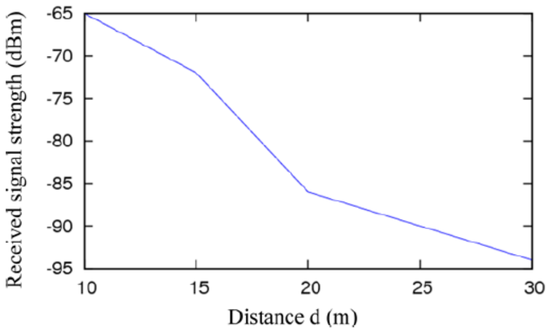

Figure 11: The incoming signal strength was determined

In practice, the position of the MICA2 board above ground may be slanted with the board buried underground. An experiment was performed to determine this effect. The experiment plan is shown in figure below.

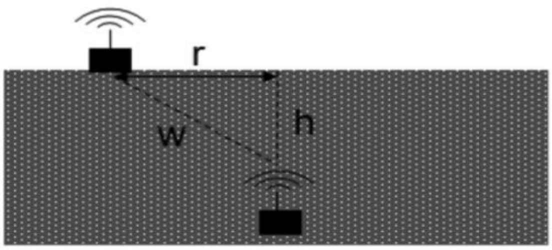

Figure 12: The experiment plan

This experiment was close to the second experiment. The MICA2 board buried underground was set up at some pre known depth, and the MICA2 board on the ground was moved away from the buried sensor location. The MICA2 board buried underground was fixed at three depths, 10 cm, 15 cm, and 20 cm. The incoming signal strength was measured and shown in figure below.

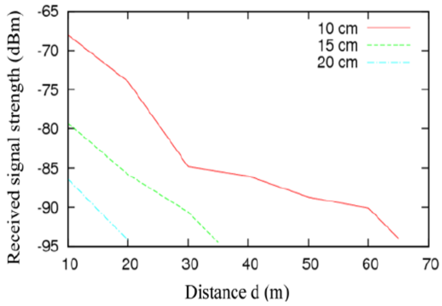

Figure 13: The incoming signal strength was measured.

As shown in that figure, the distance limit at a depth of 10 cm was 40 cm. At a depth of 15 cm, the limit was 30 cm, and, at the depth of 20 cm, it was 22 cm. By applying the Pythagorean Theorem in the experiment we'll end up having:

$$w = \sqrt{r^2 + h^2}$$

Where w is the direct underground connection between the two sensor boards. We can see it as the underground transmission depth, but this distance gets reduced if the sensor is buried deeper underground. Max values of this depth are 65cm, 76 cm, 38 cm and 28 cm if the buried sensor board is placed at depths of 10 cm, 15 cm, and 20 cm, accordingly.

One of the biggest disadvantages of wireless transmission is that there are always pipe lines that cross area far away from any sort of civilization and it becomes extremely harder to acquire the data from our wireless sensor nodes, in this situation we propose to use flying drones that have the ability of going into exact coordinated locations using GPS technology to pick up data wirelessly from our sensors nodes and return back to operators in order to analyze the data without actually going to spots that might be dangerous and far from reach and not forget the cost of making the arrangements.

V. Conclusion

The approach previously did cross-correlation method works well in metal pipes; however, the effectiveness of this case is doubtful with metallic and plastic pipes. The problems of using the present conventional correlation techniques with plastic pipes include the following: High fluctuation; this means that distances between the sensors and the type and quality of sensor are of great importance. Moreover, low frequency content; the frequency content of the leak noise is very low (<50 Hz) and therefore very hard to distinguish as a leak. Furthermore, the propagation of low frequency sound/vibration will be limited by the impedance of fittings. A method to detect pipeline features and leaks using signal processing of reflected pressure wave measurements is described. In addition, the increasing of distance led to acoustic emission signal attenuation increases too. The acoustic leak technique depend on external measurements is normally faced by some serious problems, which include greater signal attenuation in plastic pipes, greater attenuation in large diameter pipes, attenuation caused by soft soils; e.g. clay or grass, pipes buried under the water table level, and pipes with pressure less than 10 meters. Attempts to characterize leaks in pipelines by utilizing internal measurements of the acoustic signal generated by the leak were conducted using either a hydrophone. The drawback of this method is the noise gathered with wave and probably some optimization for signal (measurement) or filtering the measurement may be required

In this paper, we talked about systems utilizing acoustic emanation impacts to perceive a hole or crack and find its position. We proposed uprooting noise before handling break signals. We additionally dissected issues of underground remote sensor hubs that should be considered and proposed a structure for underground sensor hubs. In view of these examinations, we proposed a checking framework that uses acoustic emanation impacts to screen underground pipeline spillages. Our proposed framework utilizes remote correspondence so it can be effortlessly conveyed, arranged, and kept up. Analyses demonstrated that the correspondence furthest reaches of our proposed framework were 10 m on a level plane and 30 cm vertically.

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