UNDERGROUND PVC/PE WATER PIPE DETECTION SYSTEM

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ABSTRACT

With the development of technology, a lot of underground cables, wires and pipes are buried underneath. There is lot of equipment to detect metal objects, but limited equipment to detect non-metallic objects which are very expensive.

The objective of the research was to develop a low cost equipment to detect underground non-metallic pipes in either horizontal or vertical placed positions. Since this type of detection cannot be done using electromagnetic locators, an acoustic method is used to generate continuous-wave (CW) acoustic signal, which is then injected and transmitted throughout the pipe. Afterwards, the transmitted signals were captured using a seismic sensor. The data gathered was used to determine the location of the buried non-metallic pipes. The received signals were amplified, filtered and then differentiated using cross-correlation method. As a result, a reduction in unwanted signals was observed, thereby accurate transmitted signals from the actual underground pipe was captured.

DEDICATION

Thanks go to mum, dad and uncle for almost unbelievable support. They are the most important people in my world and I dedicate this thesis to them.

ACKNOWLEDGMENTS

I would like to extend thanks to the many people, in many countries, who so generously contributed to the work presented in this thesis.

Special mention goes to my enthusiastic supervisor, **Dr. Jayathu Samarawickrama**. For his tremendous academic support, but also for giving me so many wonderful opportunities.

Similar, profound gratitude goes to **Dr. Upeka Premarathne,** who has been a truly dedicated mentor. And gratefully supportive to share the special seismic sensor for my design.

I am also respect to **Prof.Rohan Munasinghe**, especially for sharing his grate full guidance,

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Finally, but by no means least, thanks go to my Mother, Father and my Uncle for almost unbelievable support. they are the most important people in my world.

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LIST OF ABBREVIATION

GPR	Ground Penetrating Radar.
CW	Continuous Wave.
EM	Electro Magnetic.
PVC	Poly Vinyl Chloride.
PE	Poly Ethylene.
NWSDB	National Water Supply and Drainage Board.
CMRR	Common Mode Rejection Ratio.
PCB	Printed Circuit Board.
IC	Integrated Circuit.
DIP	Dual Inline Package.
ADC	Analogue to Digital Conversion.
DC	Direct Current

CHAPTER I

1. INTRODUCTION

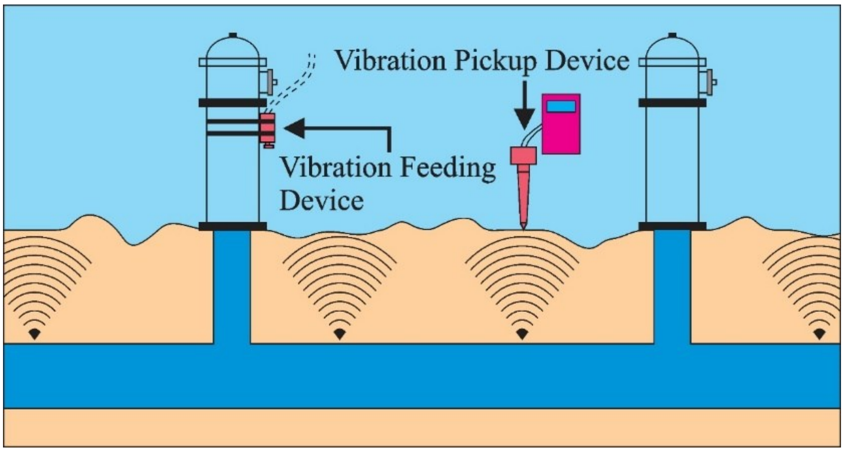

Figure 1.1 System Setup

Underground device detection systems are very popular among various sectors in the world. They use many techniques to locate objects, such as ground penetration radar (GPR) to obtain underground image and electromagnetic (EM) conductivity for locating wire or underground electrical instances, another hi-tech system introduces for exploration that is called ultra-high radio frequency technique. It was originally created for lunar exploration, which has many advantages over typical GPR technology.

Above GPR and ultra-high radio frequency technique are very expensive and use the hi-technologies. EM method fairly good but cannot be locate the poly vinyl chloride (PVC) and poly ethylene (PE) pipes.

In industry there has some demand for PVC and PE pipe locating systems in Sri Lanka. The one of the main benefiter for this is National Water Supply and Drainage Board (NWSDB). They distribute pipe borne water to the entire country using pipe. That pipe made out of PVC, metal and PE. Metal pipes can be detected using EM method but there is still no method to find PVC and PE pipes. GPR is quite a good method but this method can't distinguish the required pipe when there are a lot of lines (Electrical, water, telecommunication etc.).

However Acoustic method solves this matter and is economically feasible for developing countries.

Above Figure 1.1 shows the proposed sytem of the underground pipe detection.One end of the pipe line fix the vibration device and hand held detection system include with sensor module that use for detect the vibration.Device can grab the signal from earth and figure out the signal strength as voltage.

The acoustic method has several advantages:

- Less expensive and easily accessible compared to other technologies
- No radio frequency is needed
- Other industries benefit from acoustic detection technology include natural gas pipelines, sewer lateral among others
- Faster interpretation
- Saves time taken for excavation
- Prevents damage and keeps the globe safe

Furthermore, this acoustic method can be technically described as consisting of a SM24 GEO Sensor to pick up the seismic signal, where sensitivity of the sensor is enough for pick up the vibration signal.

Then pre amplification is done by AD524CD instrumentation op amp and a high CMRR (120dB @ G=1000). The signal limiting or level adjustment is done by using voltage divider.

The signal filtering part is done by using MAX260ACNG microcontroller programmable filtering integrated circuit (IC) capable of 4^{th} order Chebyshev or Butterworth filter design.

The main processing part is controlled by using Arduino due board and it consists of a high processing ARM Cortex – M3 CPU.

Signal strength identification process includes the analogue to digital conversion (ADC) and cross-correlation process of the signal. In this system use the cross-correlation for clarify the similarity of expected signal and receiving signal. The cross-correlation had been using for check the behavior of the signal that flow through the pipeline and through the soil also rejection of the non-similarity signal that occurred form the surrounding. Thus value of the cross-correlation is implying the similarity of the signal.

The simple technique is used to the signal level adjustment and the DC offset. because Arduino due input voltage should be 0-3.3V.

Geo sensor case is the special enclosure that is used to convey the seismic vibration to the sensor.

In this study vibration system is used to locate the underground PVC/PE detection and find the signal attenuation along the pipeline and around the pipeline.

CHAPTER II

2. LITERATURE REVIEW

2.1. Existing systems identification.

Underground pipe detecting systems are very popular in the world. The pipe would be metal, porcelain, PVC or PE.

According to the material of the pipeline that detection system must be change. It would be

1. Electromagnetic (EM)
2. Ground penetration radar (GPR)
3. Acoustic.

2.1.1. Electromagnetic Conductivity (EM)

Used for identifies the underground metallic device. Its main shortcoming is that it will not locate non-metallic lines such as PVC/PE pipes [1] [12] [13]. There are several types of systems in the industry, like hand held divice with sensor probs, two parts of unit which consist of TX and RX device.

2.1.2. Electromagnetic signal Attenuation

Electromagnetic waves propagating through the subsurface are subject to frequency dependent attenuation which depends on the effective conductivity. The effective conductivity is a function of the real component of the electric conductivity and the complex component of the dielectric permittivity [8] [11]. Below equation (1) presents the attenuation of the electromagnetic wave.

$$\alpha = \omega\sqrt{\varepsilon\mu\frac{\sqrt{1+(\sigma/\omega\varepsilon)^2}-1}{2}} \qquad (1)$$

$\mu = \mu_0 = 4\pi \times 10^{-7}\ \text{henry}/m$

$\omega = 2\pi f$

$\varepsilon_0 = 8.85 \times 10^{-12}\ F/m$

α= Attenuation

ω=Angular Velocity

ε_0 =Dielectric Permittivity of the vacuum

σ = Electrical Conductivity

2.1.3. Ground penetration radar (GPR)

Ground penetrating radar, GPR, is a high resolution geophysical method, which is based on the propagation of high frequency electromagnetic waves. The GPR method images structures in the ground that are related to changes in dielectric properties [1][7][16].

The GPR method operates by transmitting a very short electromagnetic pulse into the ground using an antenna. The center frequency is typically in the range of 10-2000 MHz Abrupt changes in dielectric properties cause parts of the electromagnetic energy to be reflected back to the ground surface, where it is recorded and amplified by the receiving antenna. The recorded signal is registered as amplitude and polarity versus two-way travel time [8] [9] [11].

2.1.4. Acoustic method.

Acoustic system is a mechanical phenomenon. Mechanical vibrations are a movement of particles around the state of equilibrium in a solid environment. Vibrations are a common phenomenon in our daily life. These vibrations are often parasite effects threatening our existence. Vibrations of the ground, machines, or a number of technical devices present a process, which require a continuous or a long-term monitoring. In many sectors vibrations are a working factor in a production process.

[4][14][15]

It is difficult to estimate to what degree the amplitude of vibration decreases at a certain distance. Generally, the attenuation of vibrations with distance is composed of two factors: geometric damping and material damping. The geometric damping depends on the type and the location of vibration source [2][5].

2.1.5. Acoustic signal Attenuation

The environmental zone, which is effectively reduce the ground vibration amplitude. However, it is difficult to estimate to what degree the amplitude of vibration decreases at a certain distance. Generally, the attenuation of vibrations with distance is composed of two factors: geometric damping and material damping. The geometric damping depends on the type and the location of vibration source and the material damping is related with ground properties and vibration amplitude [2] [5] [19] [17].

Vibrations lose energy during propagating in the ground and the amplitude of the vibrations decreases with increasing distance from the source. The decay of amplitude of Vibration with distance can be attributed to two components; geometric (radiation) damping and material damping, which may be described by the following equation [2] [18]

$$w_2 = w_1 \left(\frac{r_1}{r_2}\right)^n e^{-\gamma(r_2 - r_1)} \quad (2)$$

Where,

w_1 and w_2 are vibration amplitudes at distance r_1 and r_2 from a source of vibration.

n is a geometric damping coefficient.

γ is a material damping coefficient.

Vibration energy is reduced due to the friction and cohesion between soil particles. This attenuation due to material damping is affected by the soil type and frequency of vibration. Material damping coefficient, γ, can be represented as [2]

$$\gamma = \frac{\pi \eta f}{c} \quad (3)$$

η is a loss Factor

f is a Frequency of the wave

c is a propagation Velocity of the wave

2.2. Comparison of GPR and Proposed System

Below Table 2.1 shows the comparison between GPR System and Acoustic system.

Table 2-1 Comparison between GPR and Proposed System

GPR System	Acoustic system
Some soils like saline, shale or clay have high conductivity, which limits the GPR from penetrating the soil. [1][11]	High conductivity soil easily conveys the Acoustic Signal.
Soil density, location accessibility and crowding of surrounding utilities can also affect the GPR's success. [1][11]	Sound Pickup System (Seismic Sensor) & Control unit Connected with Screen cable so had good flexibility.
Cannot distinguish the specific object in GPR image.	Easily predict the Specific object because vibration there.
Operating this equipment and understanding the results require experience and extensive training because the equipment is non-intuitive to most beginners. [1][11]	This System is very simple but accurate. So not necessary High tech Training for that system.
Expensive system.	Affordable price range.

2.3. Survey and Program Testing

Figure 2.1 Sensor installed nearby the road

2.3.1. Center Frequency Survey

*MSO-X 3014A Mix signal Oscilloscope

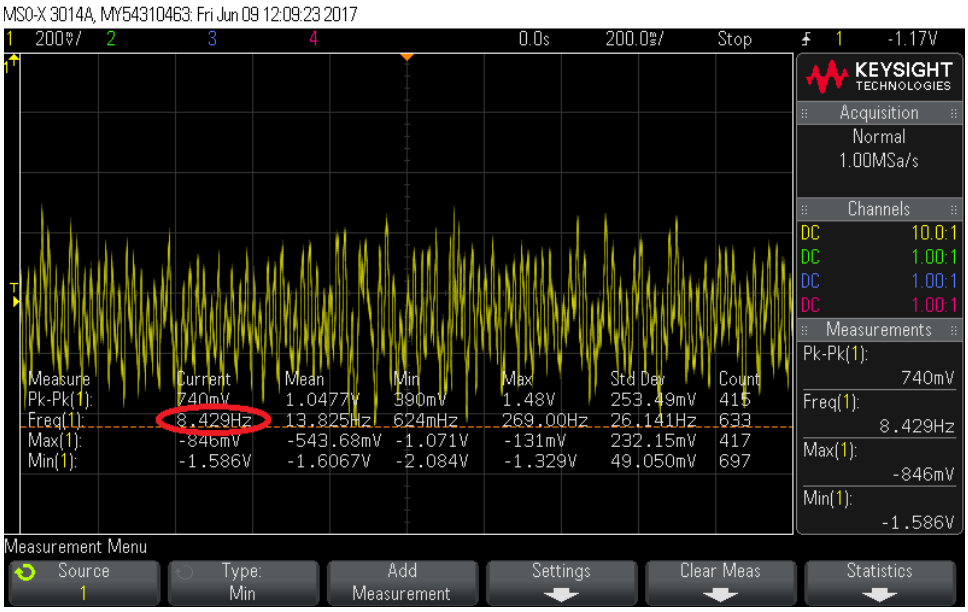

Figure 2.2 Oscilloscope result (No vehicle on the Road)

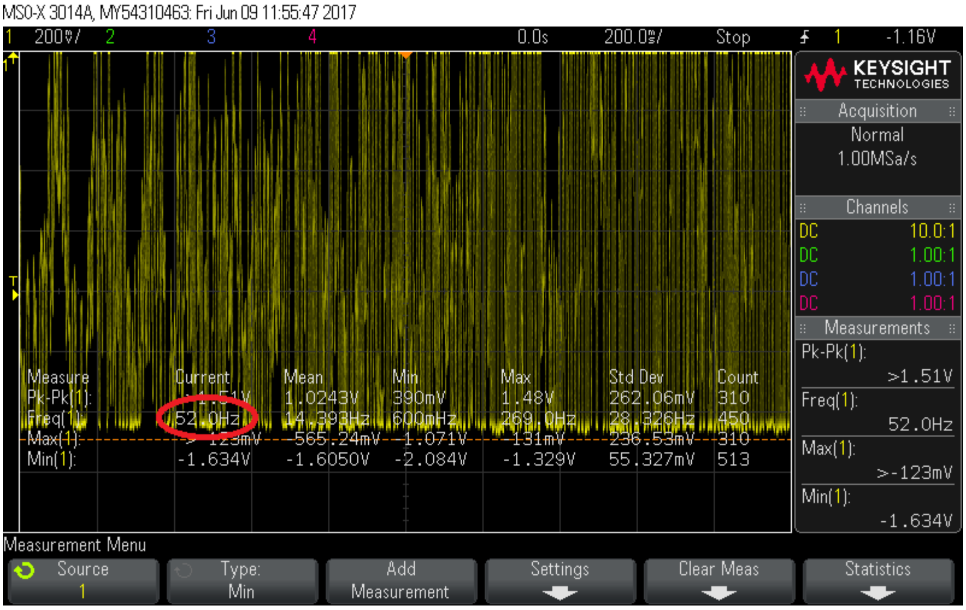

Figure 2.3 Oscilloscope result (Heavy vehicle on the Road)

Centered frequency surveying is most important to finalize the band-pass filter. The band –pass filter totally eliminate the unwanted frequencies that generate from the environment, so that have to find the range of unwanted frequencies in environment. Bellow implies the Oscilloscope* result. The sensor installed nearby the road and collects the data. Figure 2.2 and Figure 2.3 are oscilloscope result and Figure 2.1 is picture of sensor installed nearby the road.

Details taken during the survey is shown in the Figure 2.2. Current value 52 Hz figure out the frequency at the time when it was taken. According to the above result the mean value of frequency within the surveying time was 14.393Hz and maximum value 269Hz. Consider above all the matters select the center frequency (f_0) as 100 Hz.

$$f_0 = 100 \text{ Hz}$$

CHAPTER III

3. METHODOLOGY

3.1. Proposed Design

According to the problem identification in chapter ii (literature review) Table 2.1, introduced the new system to rectify the above problem. This system consists of

- Sound pick up system
- Sound (Vibration) generating and feeding system
- Power supply and battery backup system

3.2. Sound Pick up System

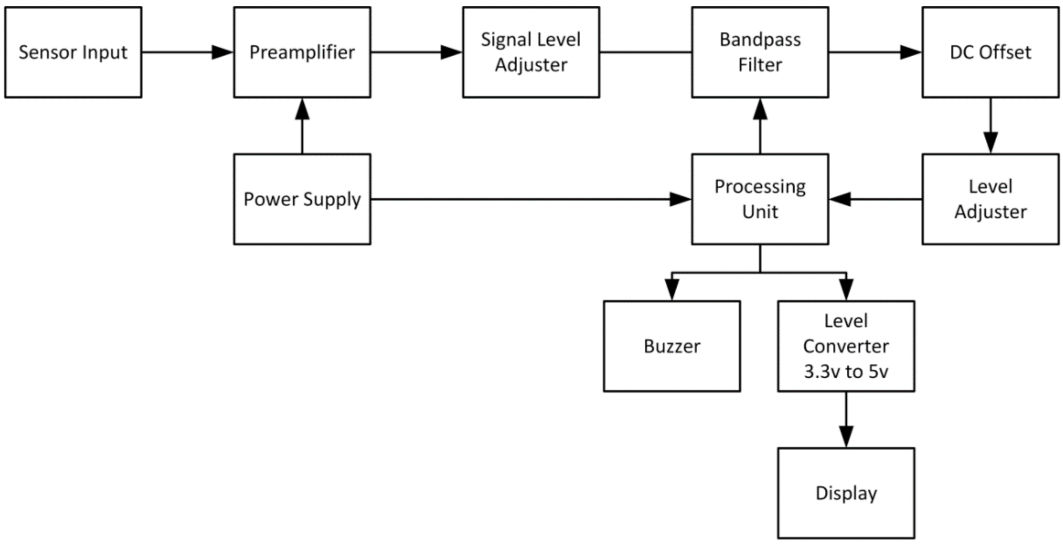

Figure 3.1 Block Diagram of the Sound Pickup System

3.2.1. **Sound Pickup Sensor**

SM-24 geophone is sensing the vibration or sounds its relatively high sensitivity than the other sound picks up sensors. Bellow Figure 3.3 shows the sensitivity with respect to the frequency. Figure 3.2 shows the physical appearance of the sensor [3] [10].

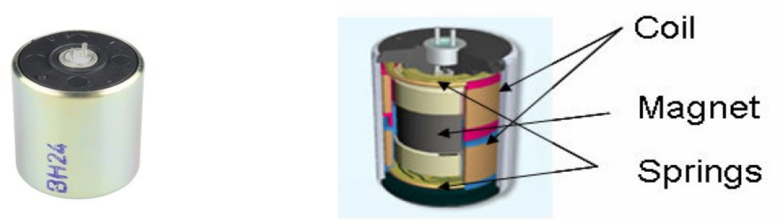

Figure 3.2 - Geophone

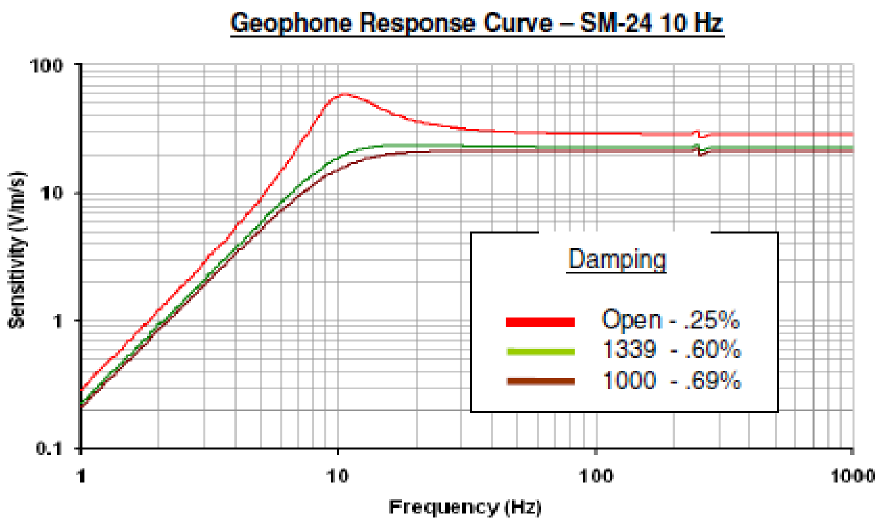

Figure 3.3 - Geophone Response Curve

3.2.2. Pre-Amplifier

Small signal amplification is done by using that block.AD524CD is instrumentation amplifier realizing that particular task. It has particular features high CMRR: 120db (G=1000), low noise and pin programmable gain 1, 10, 100, and 1000. Figure 3.4 is physical figure and functional block diagram of this op-amp (See Appendix A / A 1.1). Bellow Figure 3.5 implements the schematic diagram of the Pre–amp and Figure.3.6 implement the PCB Layout.

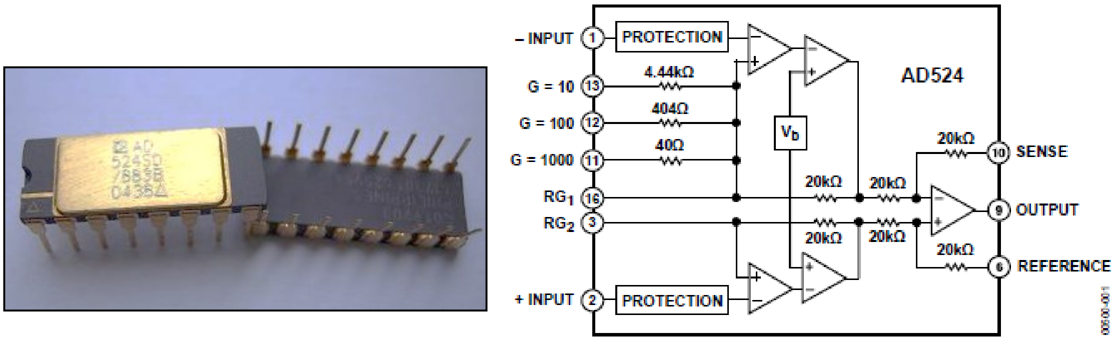

Figure 3.4 - Physical figure and Functional block diagram

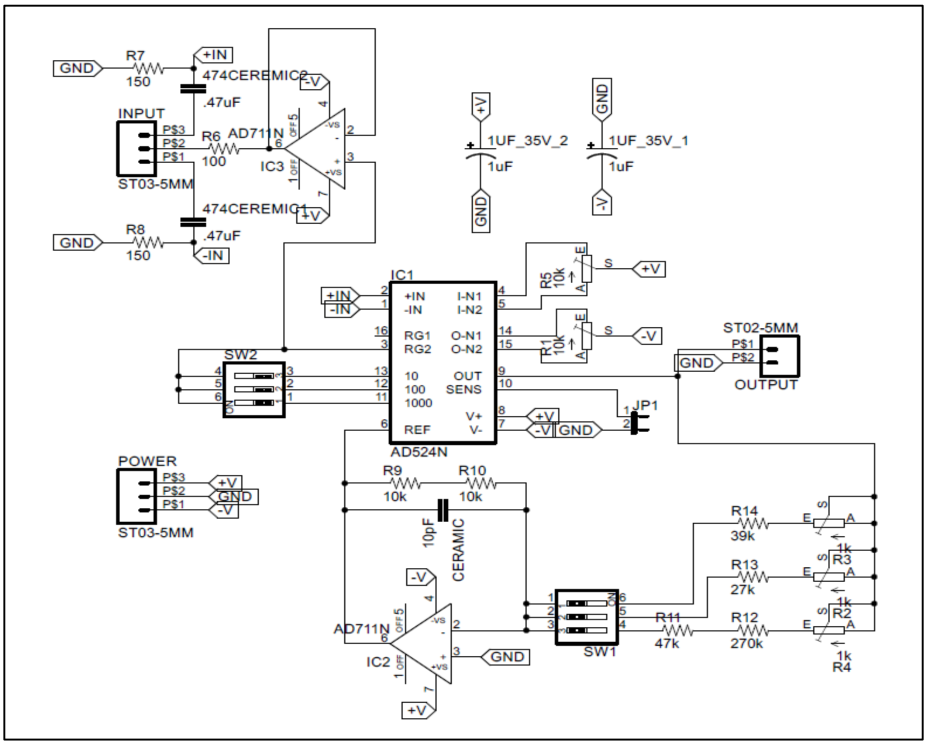

Figure 3.5 - Schematic Diagram of the Pre–amp

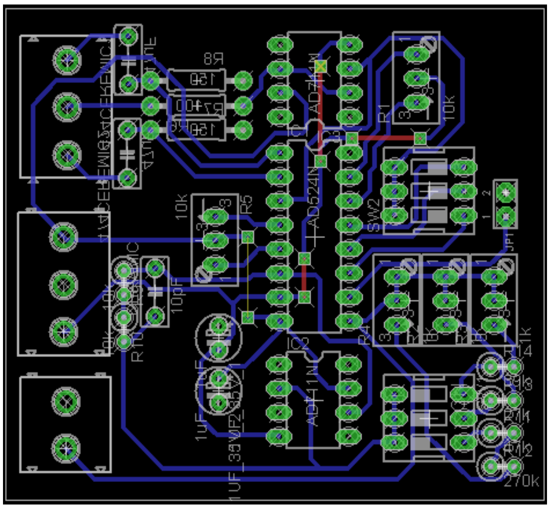

Figure 3.6 - PCB Layout of the Pre –amp

3.2.3. Filter Design

Band pass filter is selected type for this purpose. MAX260ACNG is microcontroller programmed filter IC that capable for maximum 4th order Chebyshev or Butterworth filter design. Specialty of this one is providing the software. Do not want to connect the externally resister or capacitor. Frequency range is changed according to the Mode and Q value. Figure.3.7 shows the functional block diagram and physical appearance of the IC. (See Appendix A1.2)

Bellow Figure.3.9 implements the schematic diagram of the band-pass filter and Figure.3.8 implements the PCB Layout. Here used the CD74HC374 as the buffering /leaching of the data and address lines.

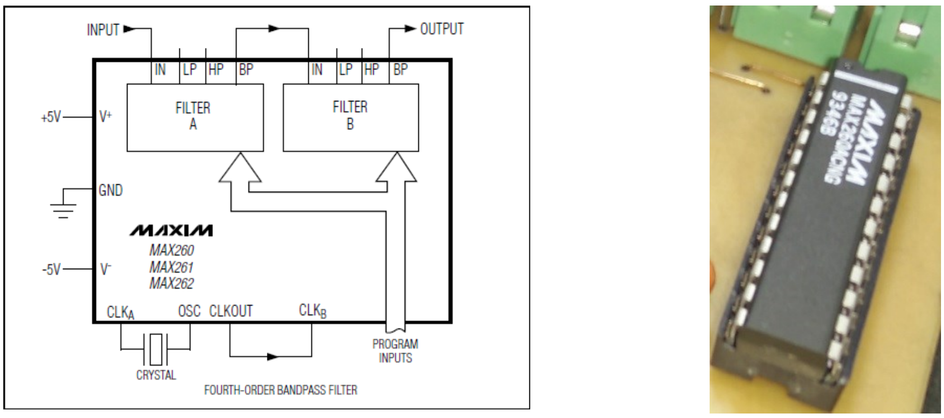

Figure 3.7 - Functional Block Diagram and physical appearance of the IC

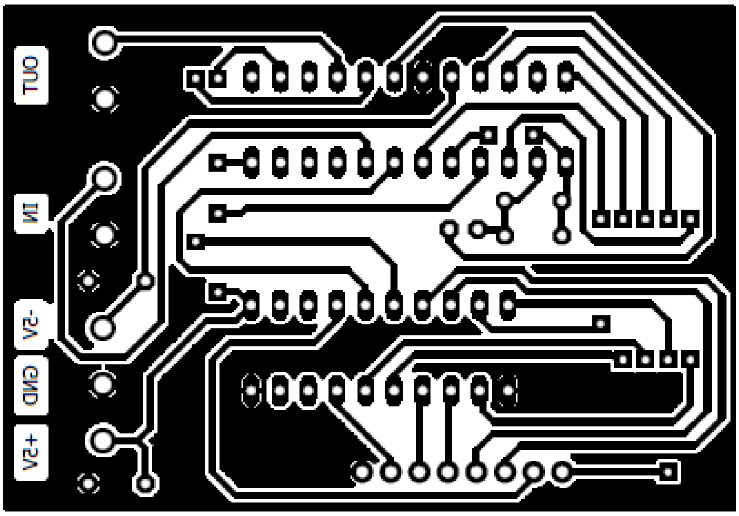

Figure 3.8 - PCB Layout of the Band-pass Filter

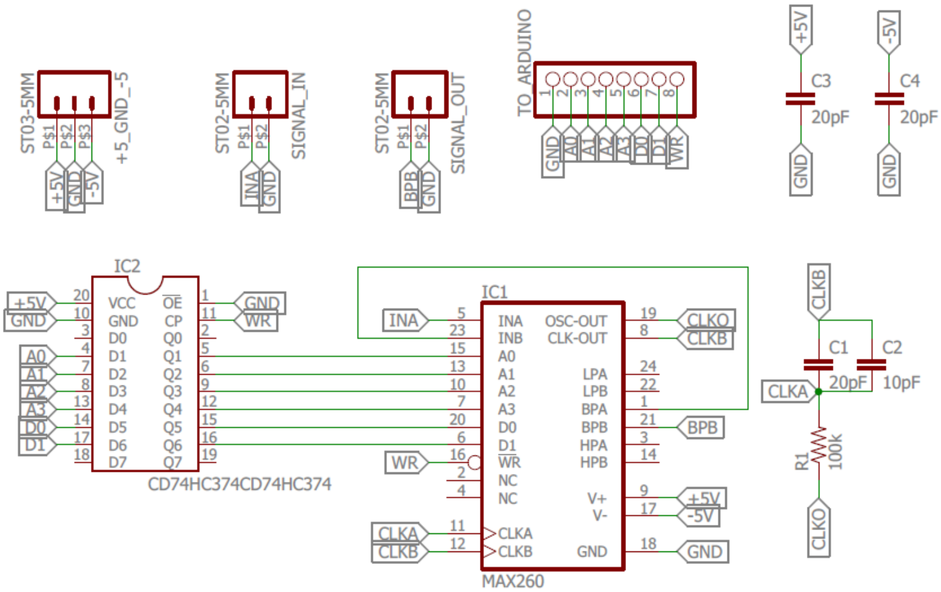

Figure 3.9 - Schematic Diagram of the Band-pass Filter

3.3. Filter Program Testing

MAX 260ACNG is a programmable filter IC, it's consists four number of address line and two number of data line as well Write Enable (WR) bellow Figure.3.10 shows the programming timing diagram.

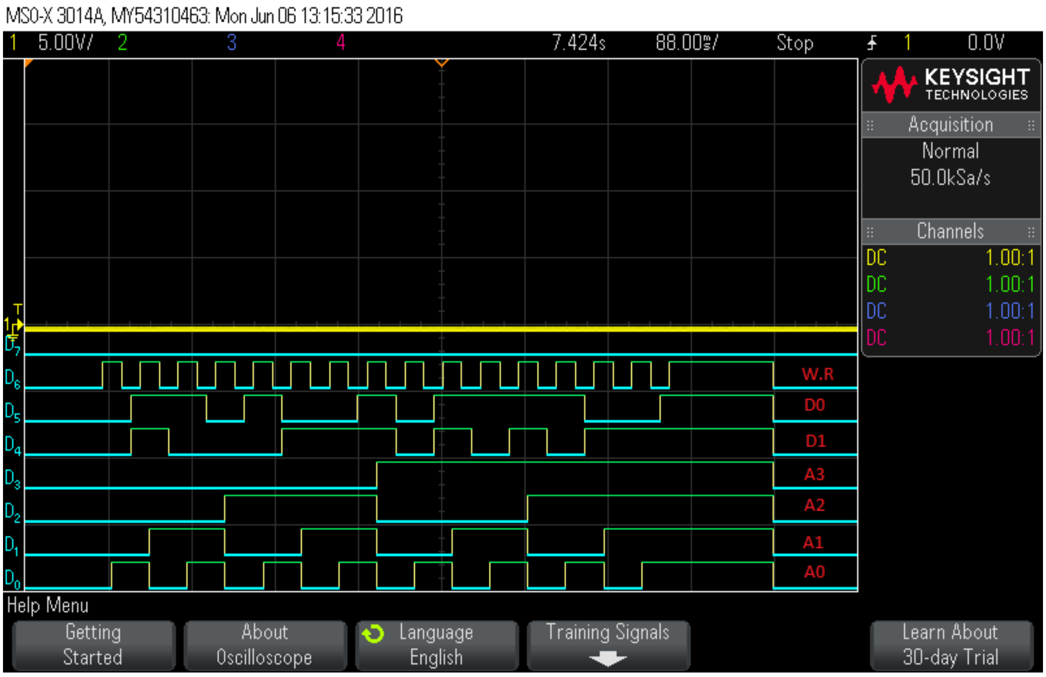

Figure 3.10 Program timing diagram

3.3.1. Processing Unit

Processing unit is the main service provider for the system. It's configure the band-pass filter, peak level detecting using A/D conversion and display the signal strength with beep sound. Arduino platform is use as the processing unit (controller board). Specially **Arduino Due** is use as this purpose. Figure 3.11 shows the detailed Arduino Due board. (See Appendix A / A1.3)

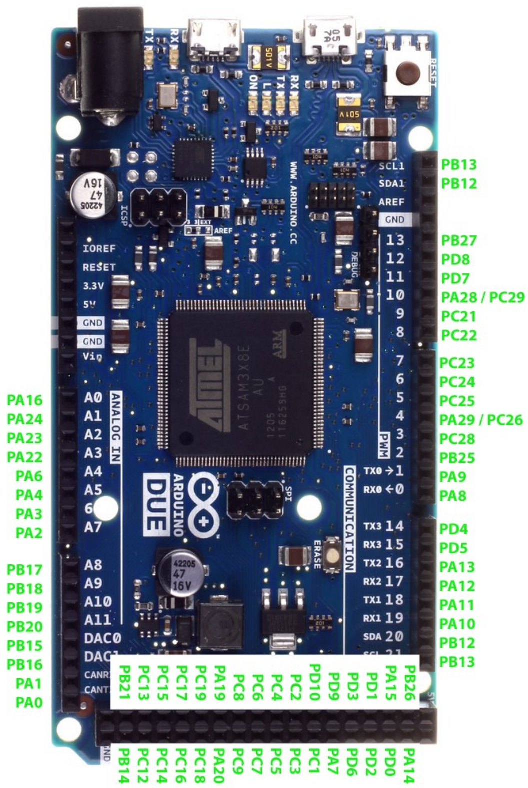

Figure 3.11 Arduino Due Board Physical Appearance and Pin Arrangement

3.3.2. Programming process flowchart

Programming process flow chart is used for gist of the process flow in a single glance.in this project mainly based on the microcontroller. The microcontroller programming and its functioning steps shows using bellow Figure 3.12. First four processes are based on initializing the system and calibration sample collection. While detecting the pipeline, it's starting the four hundred sample signal collection. Meanwhile signal correlation and analogue to digital convention processors are going on. Finally find out the maximum sensor pick up value in voltage and correlation value. Then again collect the next four hundred samples and so on.

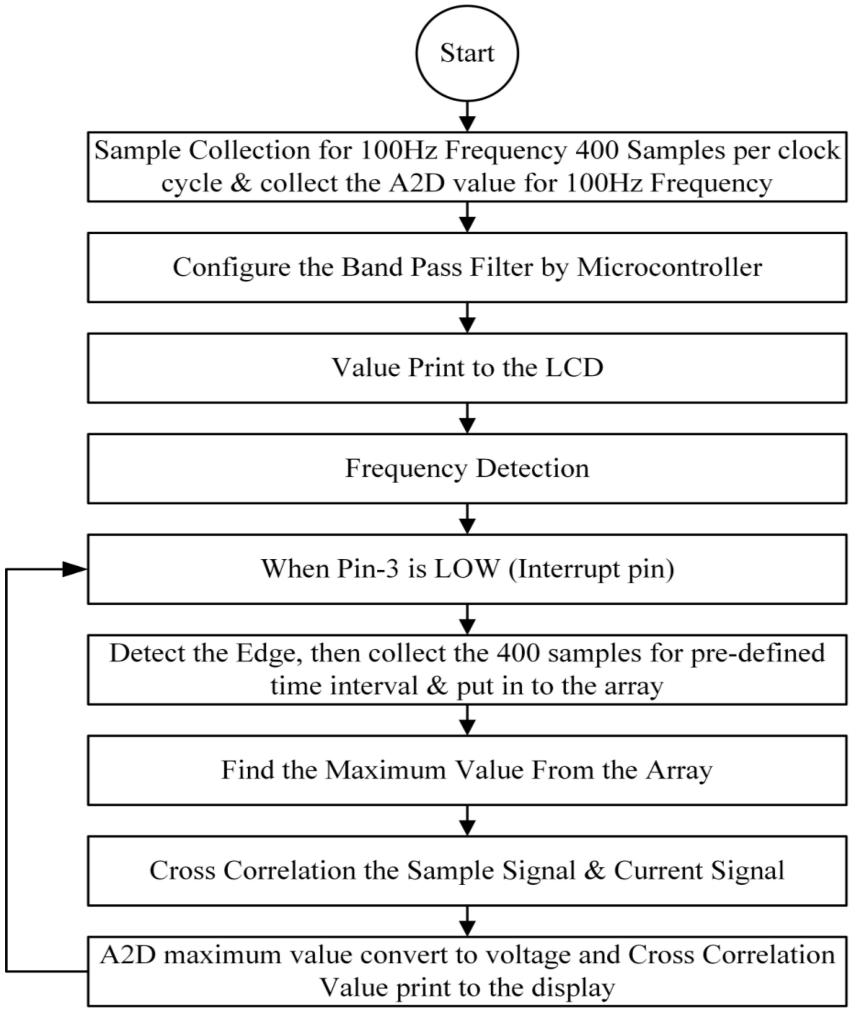

Figure 3.12 Programming process flowchart

3.3.3. Cross-correlation.

The cross-correlation is the technique which use identifies the measure of similarity between two signals as a function of the displacement of one relative to other which is known as sliding dot or inner product. This will be given a single value of similarity. The equation describe as follows (4).

$$\mathrm{Corr}_{x,y}(\tau) = \sum_{n=-\infty}^{n=+\infty} x[n]y[n+\tau] \tag{4}$$

τ – Displacement

3.3.4. Signal Level Adjuster & DC Offset Circuit

Signal level adjuster use for prevent the signal clipping when pre-amp amplifies the signal it's may be clip, so have to adjust the signal level it's use just simple method like voltage divider, use the multi turn preset for above purpose.

Figure.3-13 shows the signal level adjuster schematic. The microcontroller operates 0-3.3V voltage range. This DC offset circuit adjusts the signal between 0-3.3V. Bellow schematic consists of simple Op-Amp summing circuit. Figure 3.14 DC offset schematic.

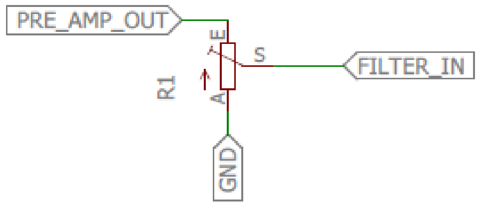

Figure 3.13 Shows the Signal Level Adjuster Schematic

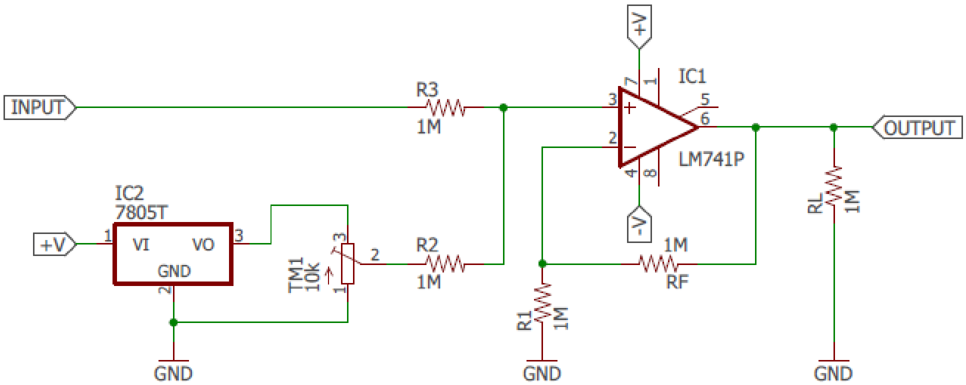

Figure 3.14 Shows the Clamping Schematic

3.4. Power Supply

Pre-amp and Filter IC both are dual power (+/-). So have to design the dual power supply. For that purpose, use the L7809, L7909 & L7805, 7905.Bellow Figure.3.15 implement the schematic and Figure 3.16 implements the PCB layout of the circuit.

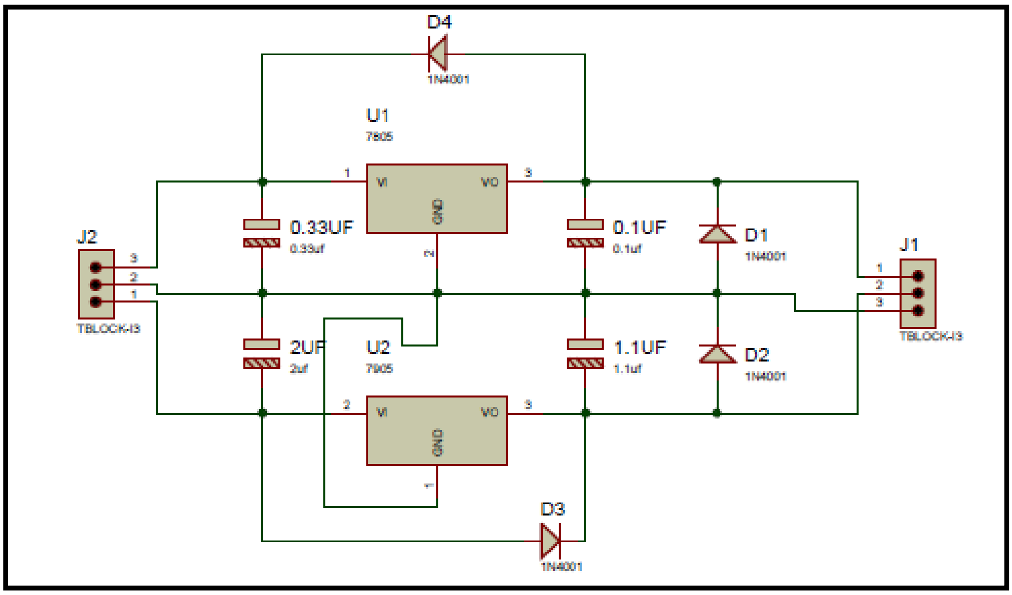

Figure 3.15 Dual Power Supply Schematic Diagram

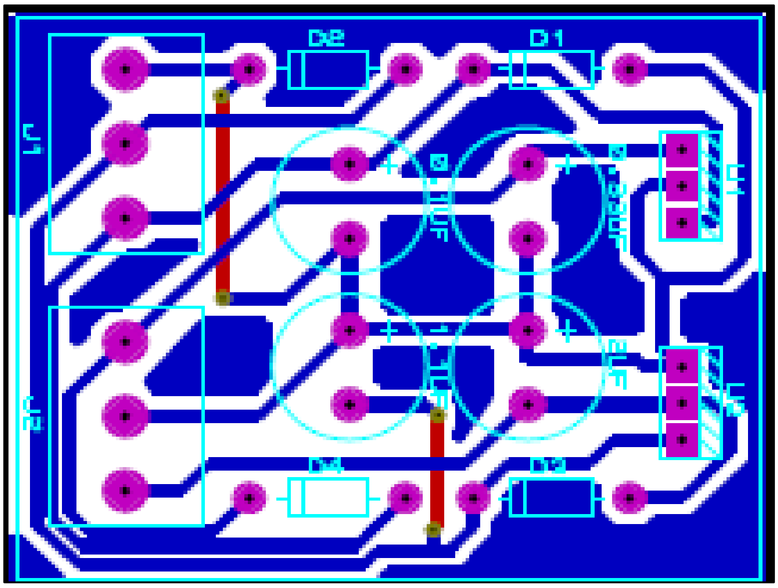

Figure 3.16 Dual Power Supply PCB Design

3.5. Vibration Generating and feeding System

Use the vibration motor as the vibration mechanisms because this is the system that consists of counter weight for properly vibrate it can be easily fixed with the PVC/PE [6]. This is roughed system and longer lasting than the other systems. Figure .3.17 shows vibration motor.

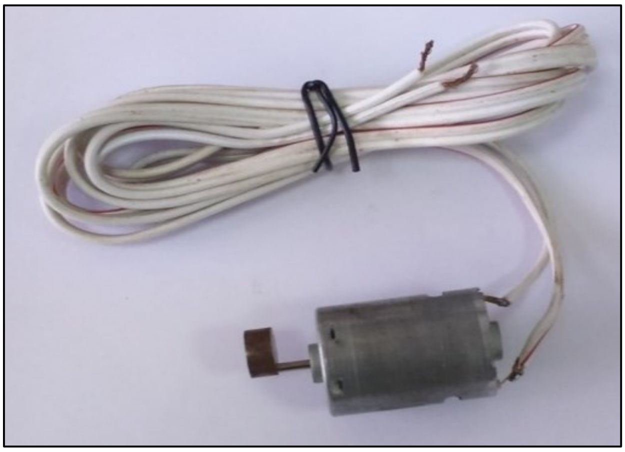

Figure 3.17 Vibration Motor

3.6. Geo Case design and Hardware Assembling

Geo cases are designed to operate reliably in the harshest environments. Fully water tight with stress relief components. Easy internal access for geophone and taper design spike mounting point. Design allows for easy deployment and snag free recovery.

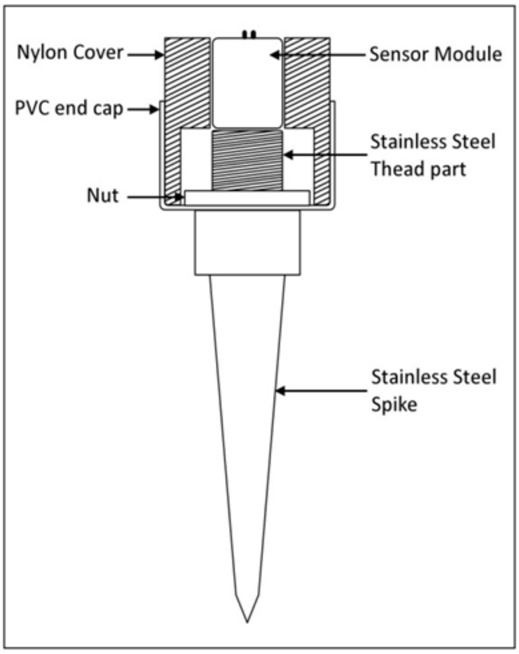

Figure 3.18 Geo Case Section View

Bellow Figure.3.18 shows the geo case section view and Figure 3.19 to Figure. 3. 28 show the design steps.

Figure 3.19 Steel Spike with Geo Sensor

Figure 3.20 Steel spike with PVC end cap

.

Figure 3.21 Sensor container

Figure 3.22 Sensor container with geo sensor

Figure 3.23 Steel spike with geo sensor container

Figure 3.24 Steel Spike & Sensor Container

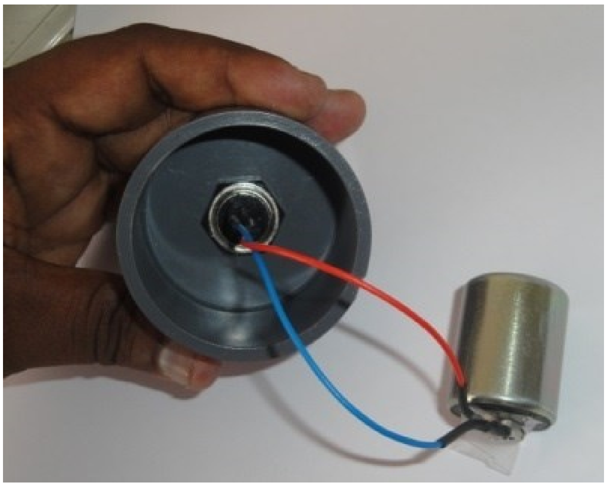

Figure 3.25 Sensor connected with PVC end

Figure 3.26 Complete sensor module

Figure 3.27 Sensor module cable

Figure 3.28 Complete sensor module with cable

CHAPTER IV

4. RESULTS

4.1. Sensor calibration results evaluation

To ensure accurate measurements, it is essential to perform calibrations.SM-24 is the main sensor for this research. The total description of that sensor will be described by the 3.2.1. Sound pickup sensor section. Here describes the total system of sensor calibration procedure.

4.1.1. Sensor calibration equipment

Figure 4.1 Micromate vibration measurement Equipment

Above Figure 4.1 shows the calibrated equipment. It is designed by the instantel company which model was Micromate. The purpose of this equipment is for detect the vibration and sound / noise or air pressure. The vibration pickup from the tri axial geophone and sound/noise or air pressure pick up from the Microphone. However, in this test only use the tri axial geophone. See Appendix A1.4 instantel Micromate specification for detail description.

4.1.2. Sensor calibration procedure

- The vibration motor is installed on flat surface and kept the tri axial geophone and SM-24 sensors adjacently.
- SM-24 sensor is connected with pre-amplifier and output of the pre-amplifier is connected to the oscilloscope.
- Micromate equipment is assembled and started the data collection.

Bellow figure.4.2 shows the 25Hz-110Hz data collection of Micromate equipment Vs SM-24. All measurements are in Hz.

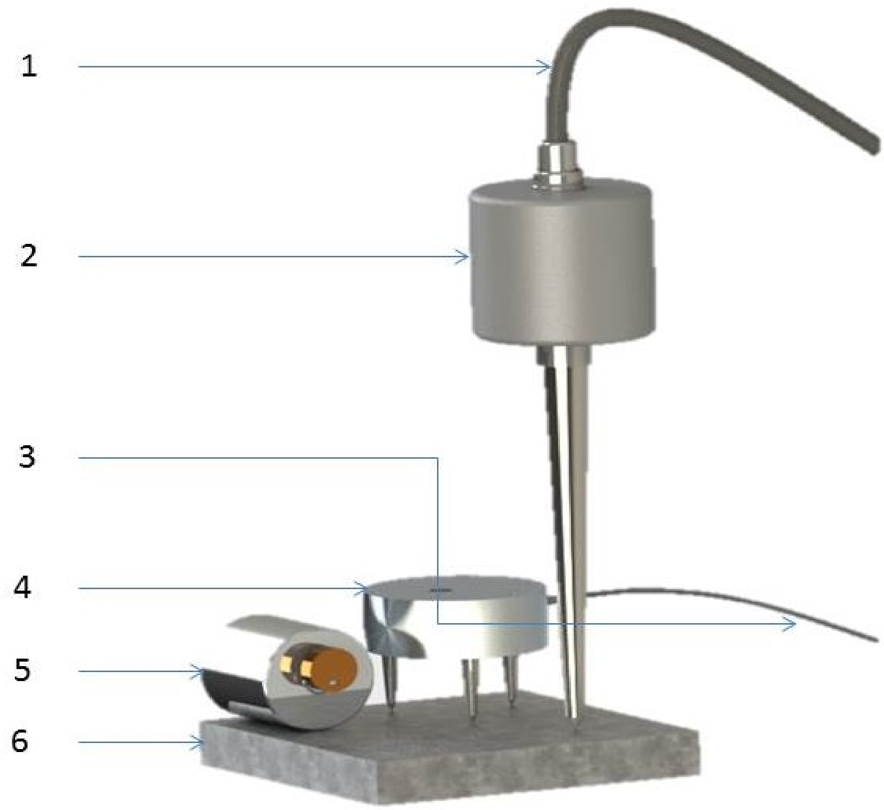

Figure 4.2 Calibration test setup

SM-24 Sensor module Output wire – Connected with Osillosope.

1- SM-24 Sensor with land case.
2- Tri-axial geophone-connected with Micromate equipment.
3- Tri-axial geophone.
4- Vibration motor.
5- Table

4.1.3. Sensor calibration result

Below Figure 4.3 presents the calibration result. According to the result error should not exceed the 1.5Hz.

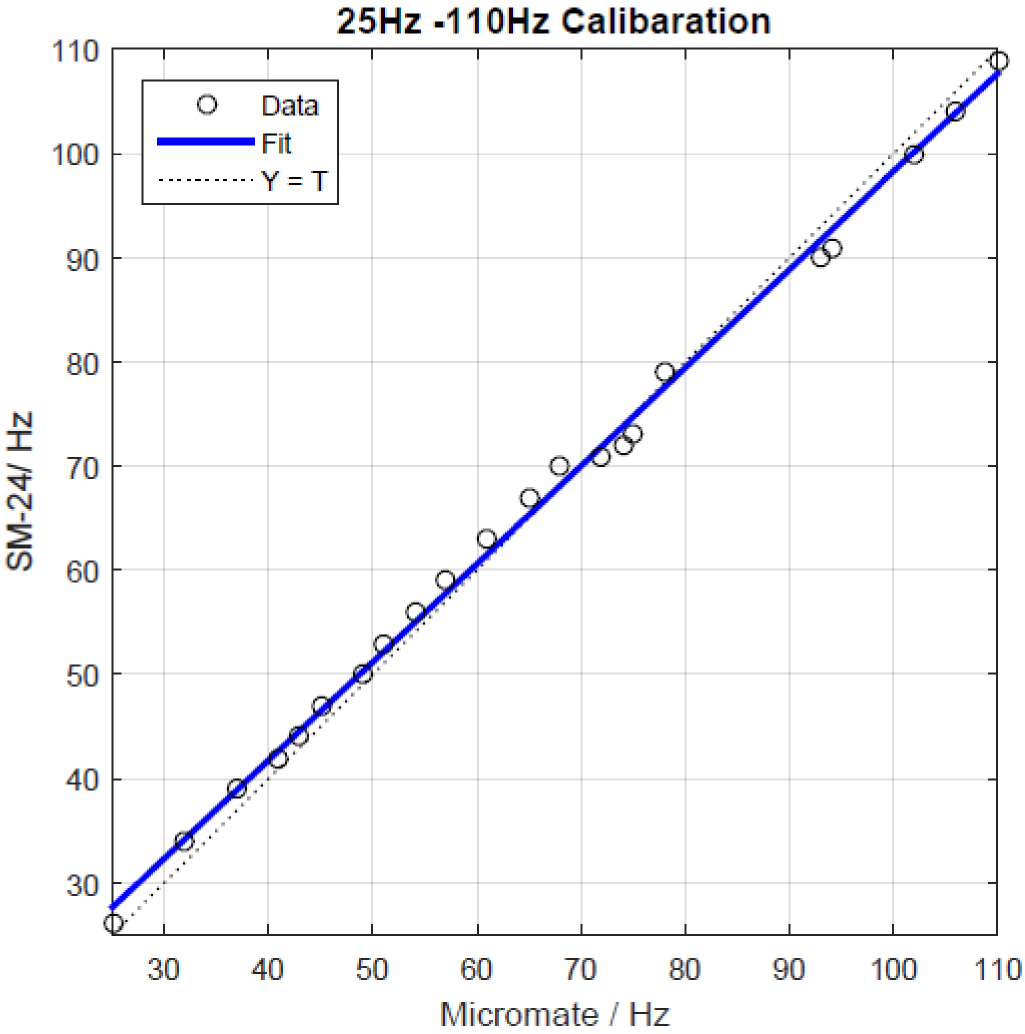

Figure 4.3 25Hz-110Hz Calibration Result

4.2. Field work test result evaluation

These test results obtain from the field work. There are consisting of three types testing platforms

1. 20mm/1000 PVC water carrying tube
2. 40mm/1000 PVC cable carrying tube
3. 30mm/1000 water carrying tube

After that, fixes the vibration motor beginning of the pipe line. That is powered using variable dual power supply. The vibration motor tightly fixes with water tube using plastic tie wraps. Bellow Figure 4.4 shows the setting out the measurement area. Figure 4.5 shows the method of measurement around the pipe line and Figure 4.6 shows the distance between two tests points. The all data measured using designed PVC/PE water pipe detection system (See Appendix A).

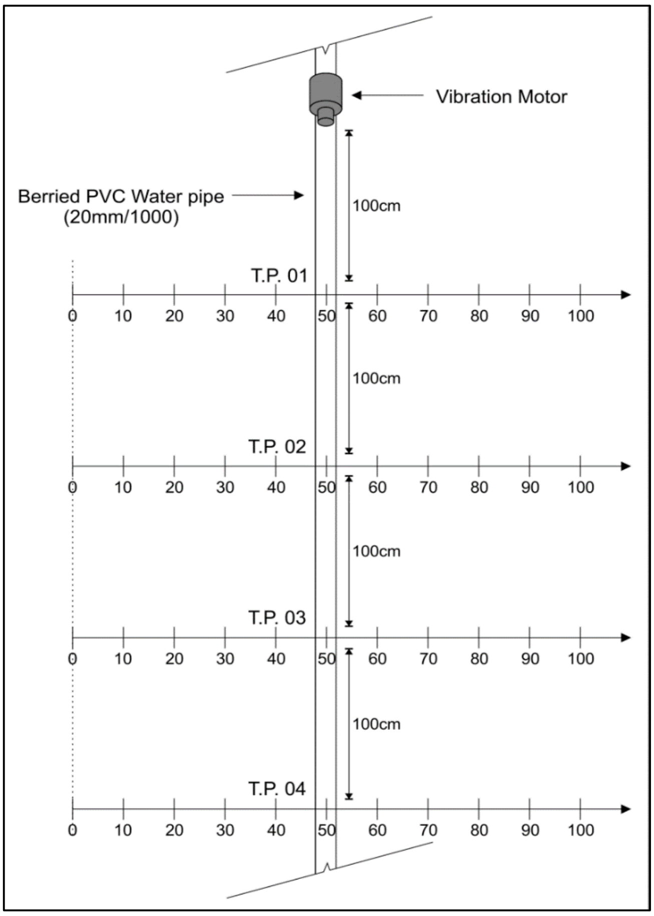

Figure 4.4 20mm/1000 PVC Measurement

4.3. 20mm⁄1000 PVC water pipe testing

Figure 4.5 Distance between Two Tests Points

Figure 4.6 Method of measuring around the pipeline

4.3.1. Test point – 1 Result

Bellow Figure 4.7 shows voltage distribution around the pipe line at the test point -1. It is on top of the pipe line (50cm point) had the highest signal voltage and the signal gradually decreased from either side as it moved outwards from the 50cm point.

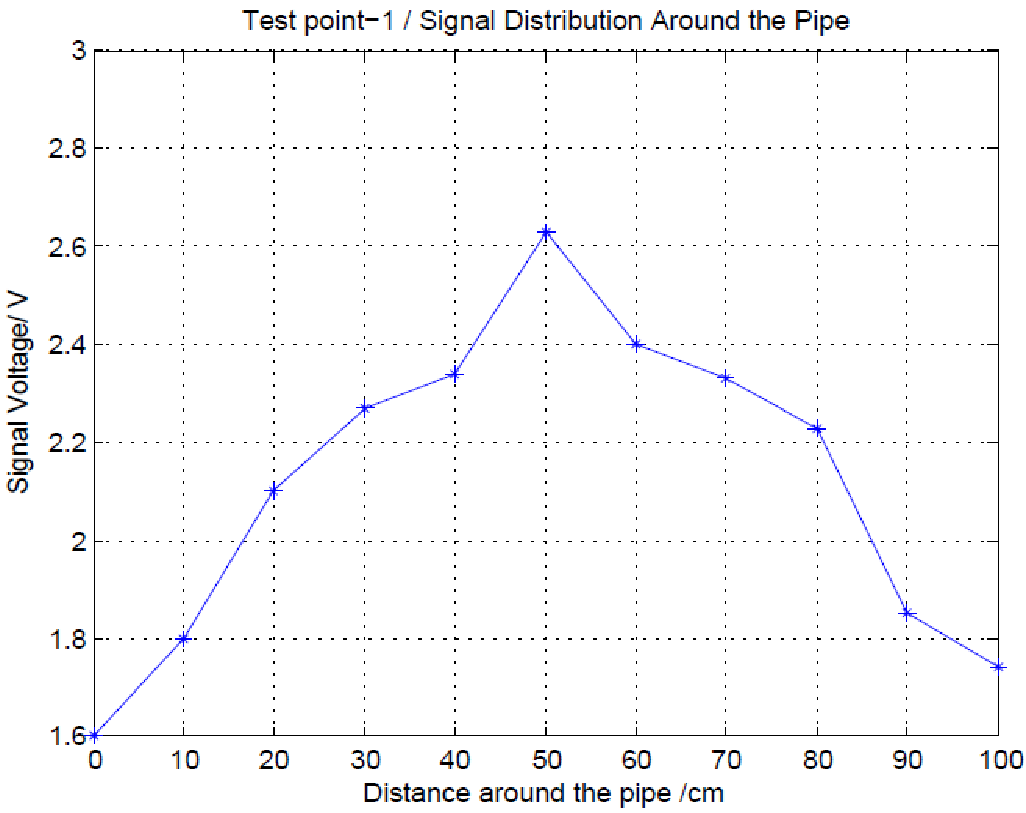

Figure 4.7 Test point – 1 Signal Distribution

4.3.2. Test point – 2 Result

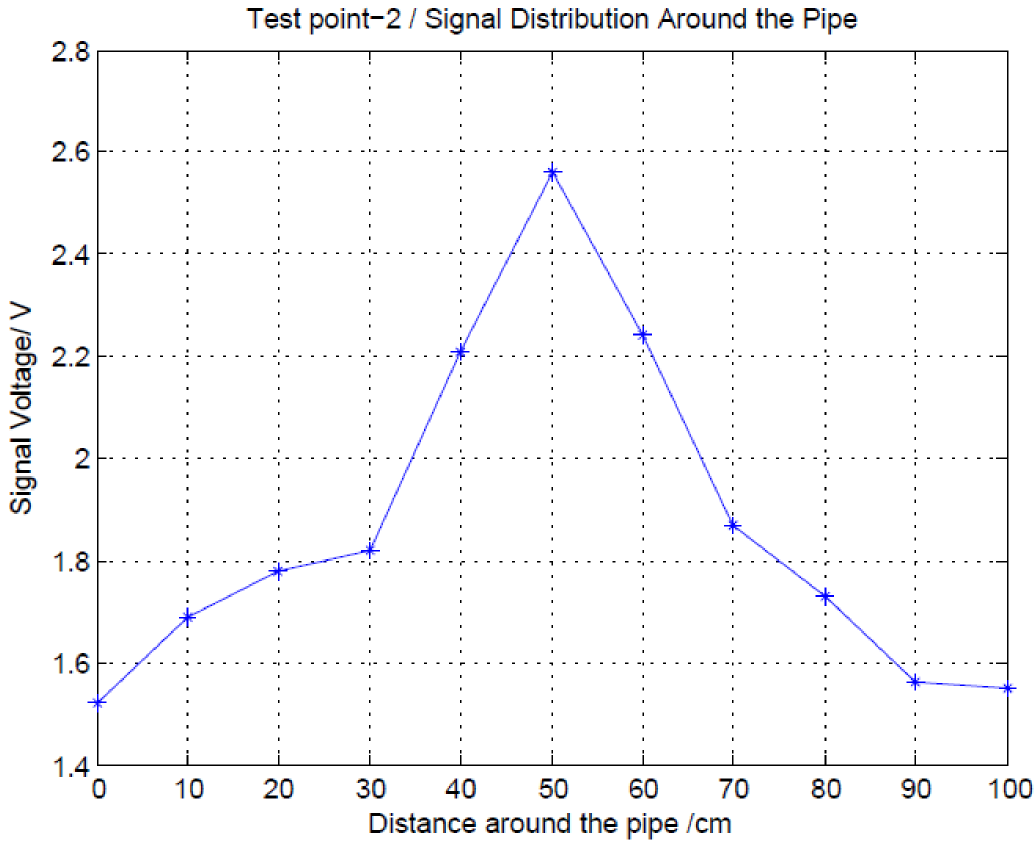

Figure 4.8 Test point – 2 Signal Distribution

Around the second test point results are most probably same as the first one. Figure 4.8 shows the test point – 2 voltage distribution. Center points (50cm) had the highest signal voltage while 40cm and 60cm points had a very much lesser value and similarly 30cm and 70cm points had even lower and gradually decrease as it moved away from the center. However, through other points regard to the test point -2 are slowly decreased.

4.3.3. Test point – 3 Result

A Figure 4.9 shows the test point-3 signal distribution around the pipe line. The 40cm and 60cm points signal levels are significantly dropped down by the distance from the vibration motor and soil condition. These points are laid 3m behind from the vibration motor and apply the reasonable soil layer. However, above mention test point's results are considerably attenuating than test point -1 and test point-2 results.

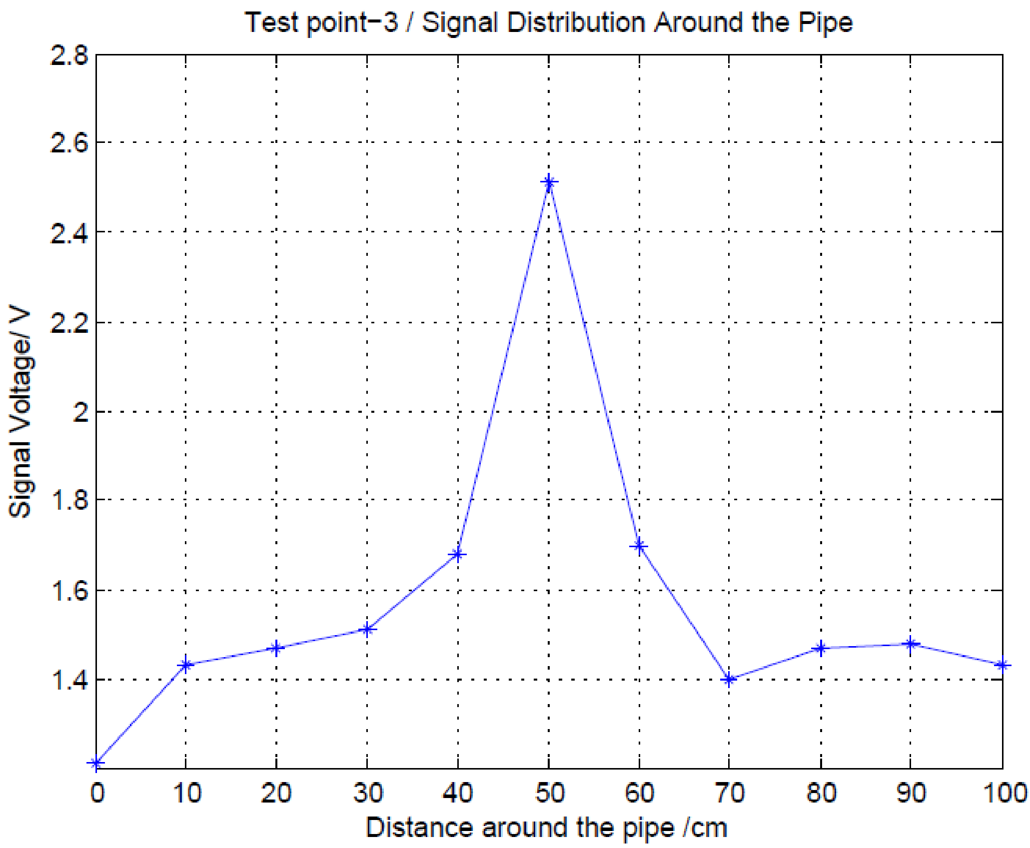

Figure 4.9 Test point – 3 Signal Distribution

4.3.4. Test point – 4 Result

Figure 4.10 is given the test point- 4 signal voltage distribution. 40cm and 60 cm points are presented the suddenly drop levels; those are more attenuated than the other test points.

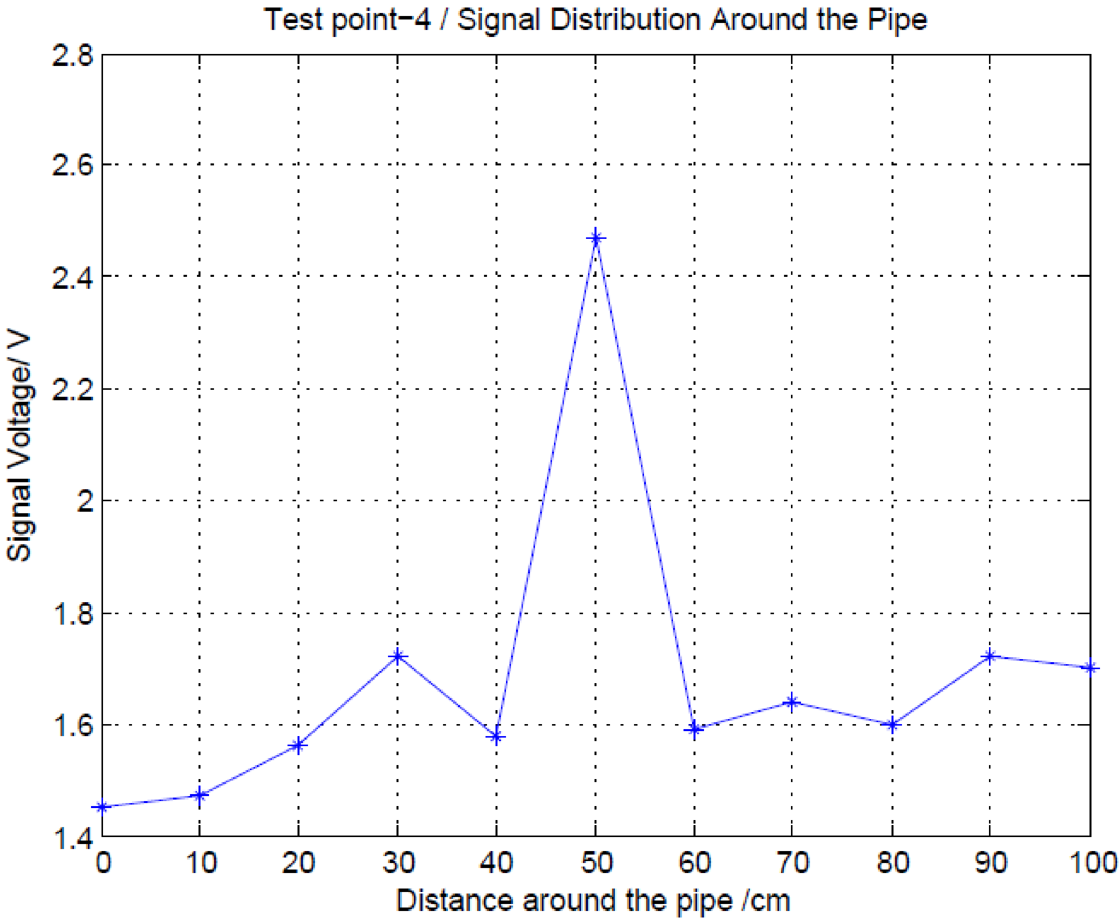

Figure 4.10 Test point – 4 Signal Distribution

4.3.5. All Voltage Signal - Test Points

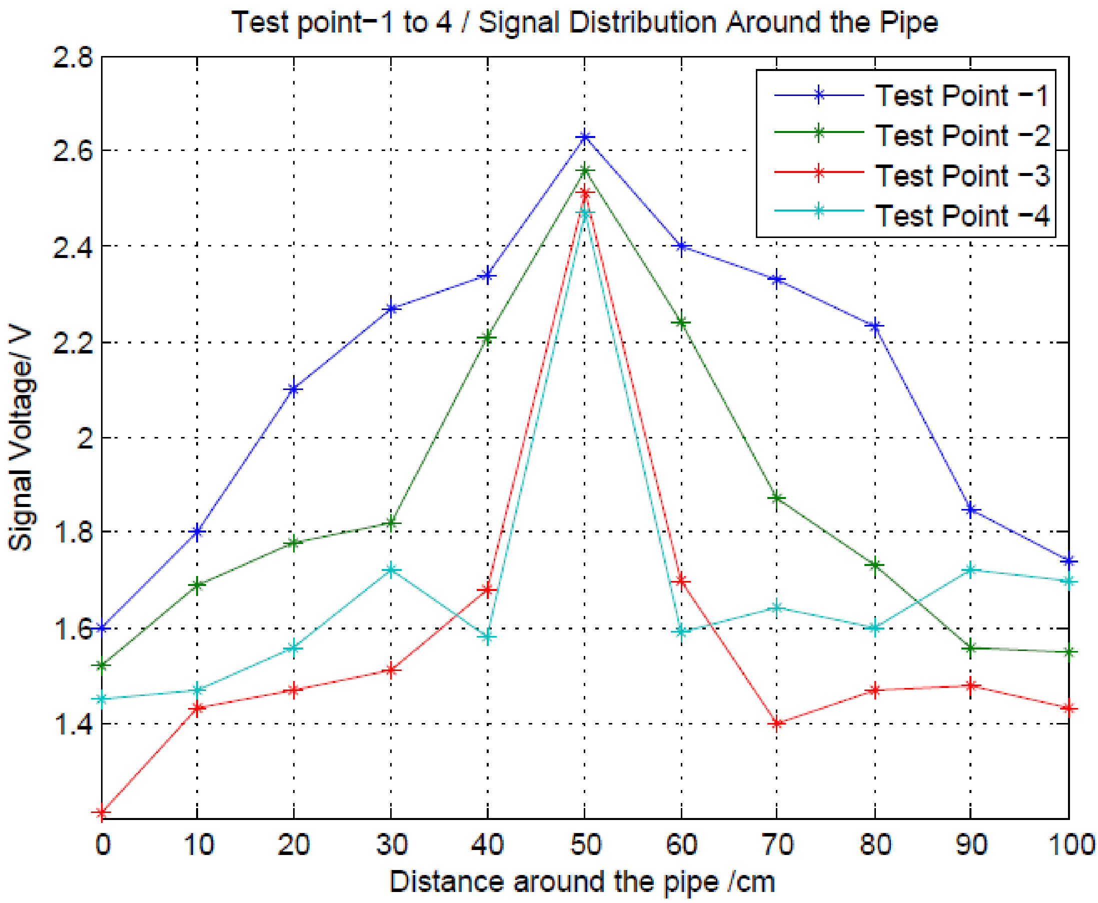

Figure 4.11 All test points signal Distribution

Figure 4.11 shows the all four-point voltage signal distribution, when consider about the 50 cm position it is on top of the pipe line, it is not much attenuate, however, with distance around the pipe line the soil condition and absorption are heavily impact the signal.

It is clearly implying the 40cm and 60 cm points, when compare with the test point 1 and 2 with test point 3 and 4.

4.3.6. Signal distribution on top of the pipeline.

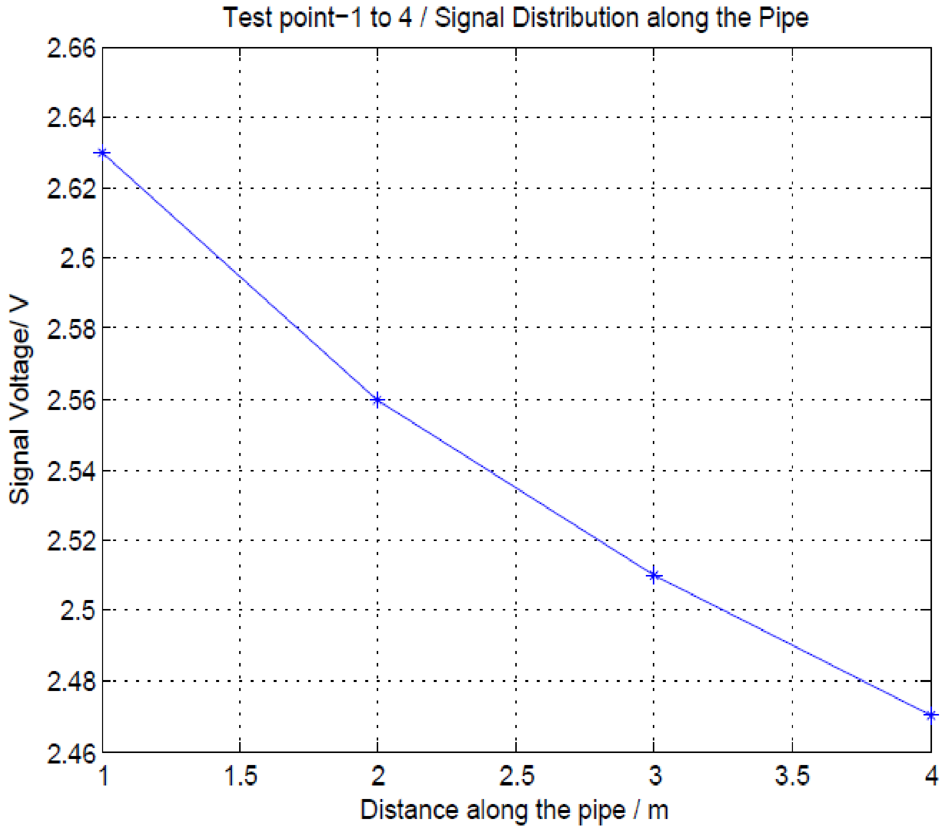

Figure 4.12 Signal distributions along the pipeline

Above Figure 4.12 shows the voltage distribution along the pipeline. When comparing with middle points results (on top of the pipeline i.e.50 cm point). Those are slightly attenuate. Reason of the occurring might be solid PVC outer, because solid substrate is the best sound propagation medium.

Due to that reason negative gradient line creates. Gradient between the first and second point is

$$gradient(m) = \frac{2.63-2.56}{1-2} = -0.07 \quad (5)$$

4.4. 40mm/1000 PVC cable pipe testing

This test, considers the 40mm/1000 PVC pipe which conveys the bunch of cables and soil condition was dry and compacted. The depth of the pipeline should in between 10 to 13 inches. There are three numbers of test points. First test point and vibration motor apart from the 100 cm distance. Around each test point horizontally divided ten segments which are labeling zero (0) to hundred (100) in milimeters bellow Figure 4.13 shows the field setting out.

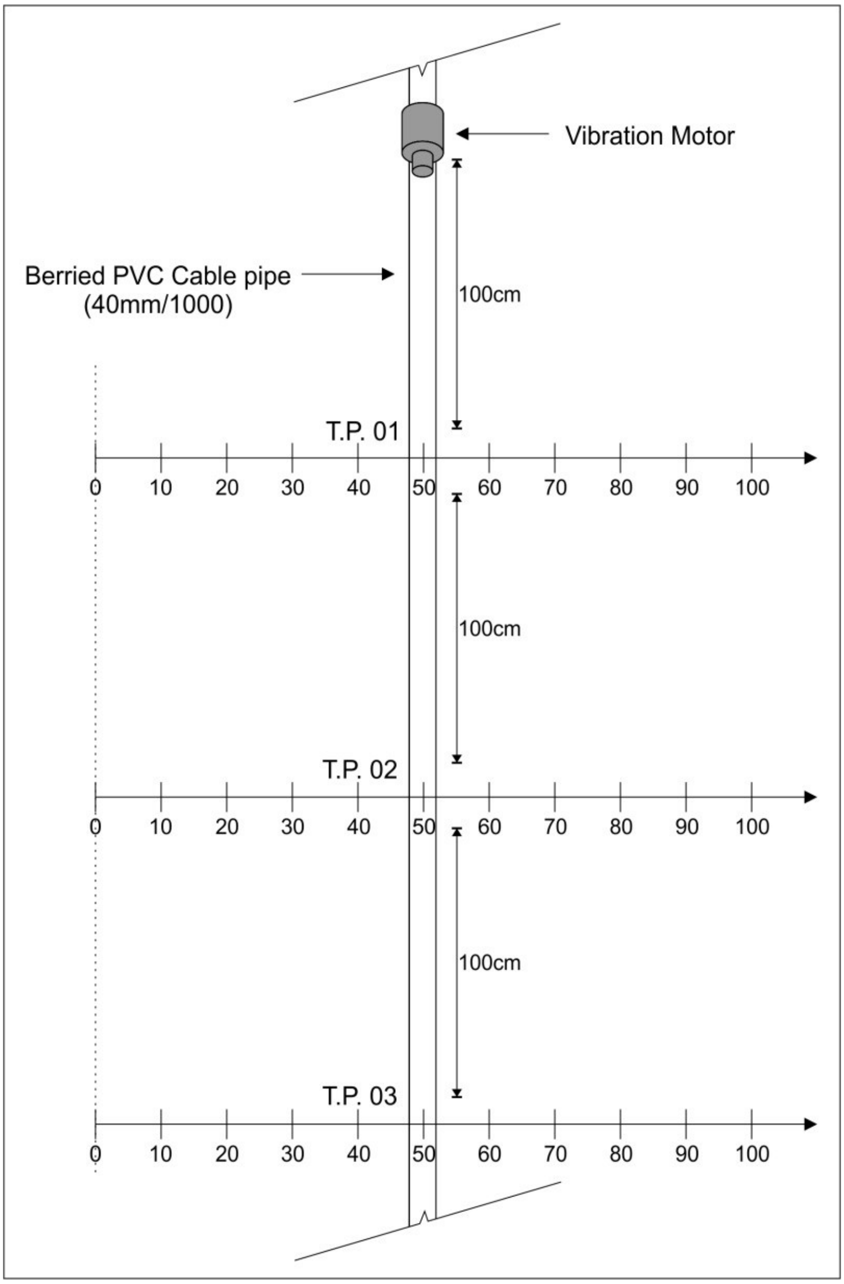

Figure 4.13 40mm/1000 PVC Measurement area setting out

4.4.1. Cable pipe line - test point – 1 result

Figure 4.14 shows the results of test point -1 for the cable carrying pipeline. The maximum value appears on top of the pipe (50cm point) and points signals decay beyond that.

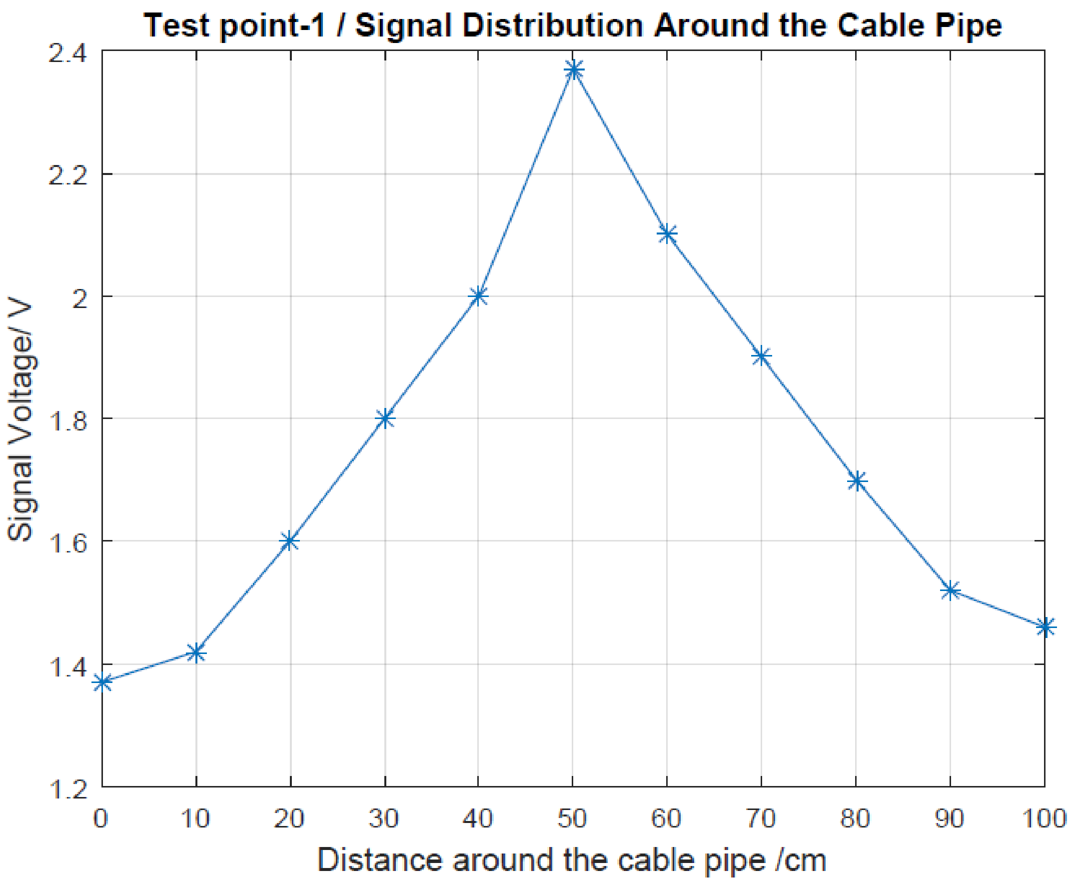

Figure 4.14 Cable pipe line test point – 2 Signal Distribution

4.4.2. Cable pipe line - test point – 2 result

Bellow Figure 4.15 presented the signal distribution graph of test point -2. This 40cm and 60cm points are attenuated than the test point – 1 and slightly signal decay in either side.

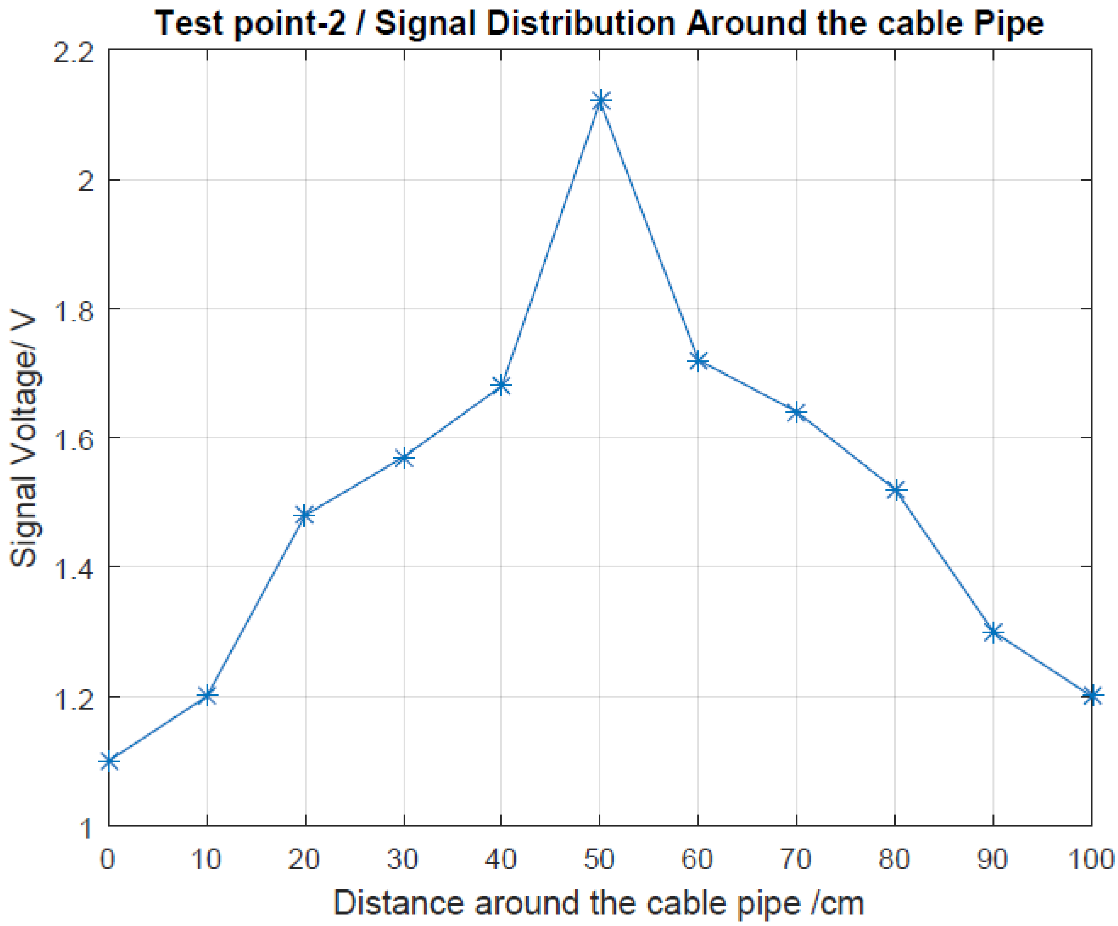

Figure 4.15 Cable pipe line test point – 2 Signal Distribution

4.4.3. Cable pipe line - test point – 3 result

Below Figure 4.16 shows the point-3 signal distribution graph which located 3m far away from the vibration motor. However signal attenuation of either side and through the pipeline slightly higher than the test point – 2.

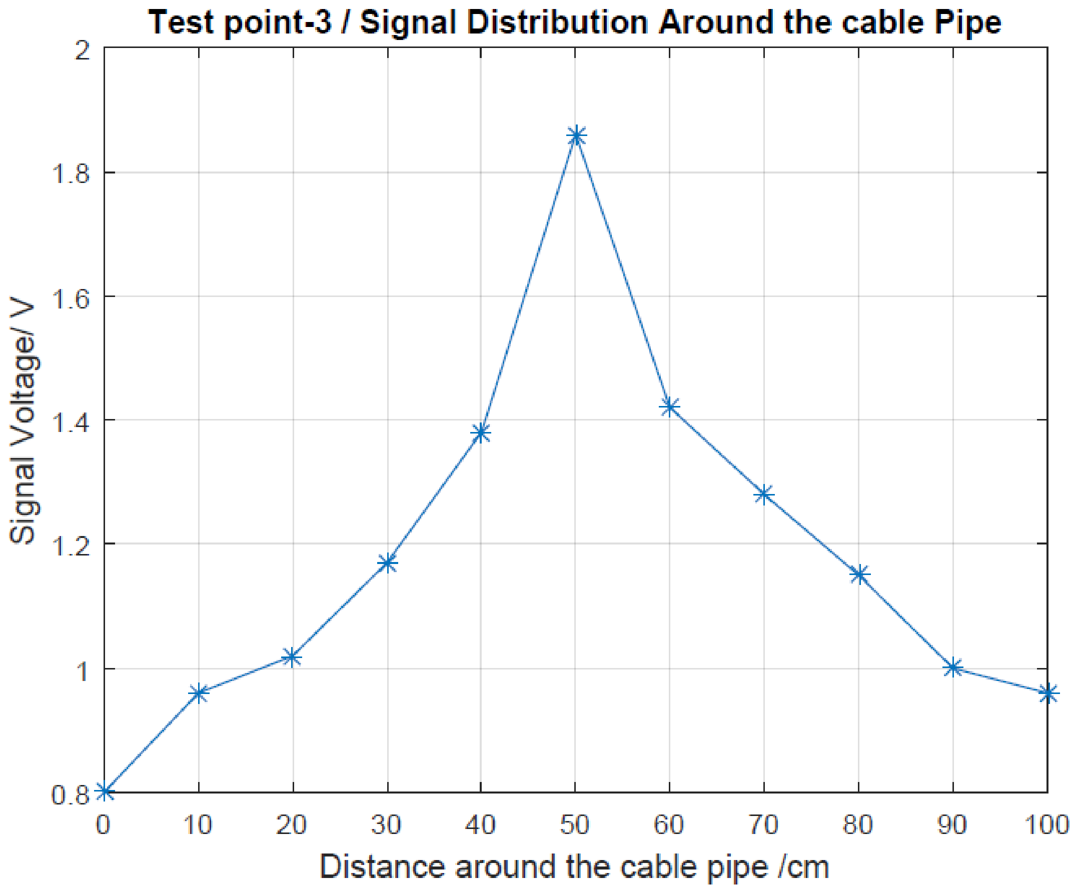

Figure 4.16 Cable pipe line - test point – 3 Signal Distribution

4.4.4. Cable pipe line - All test points result

Figure 4.17 presents the all test point signal distribution result. The graph clearly shows the signal behavior on top of the pipe and either side. The 40cm and 60cm point clearly differ from the other points and rate of the change between the 50cm-40cm and 50cm-60cm are showing very high.

When consider about the Figure 4.11 in 20mm/1000 water PVC pipe and Figure 4.17 in 40mm/1000 cable carrying PVC is implied the vibration signal behavior around the PVC pipes and vibration attenuation pattern due to the soil and depth.

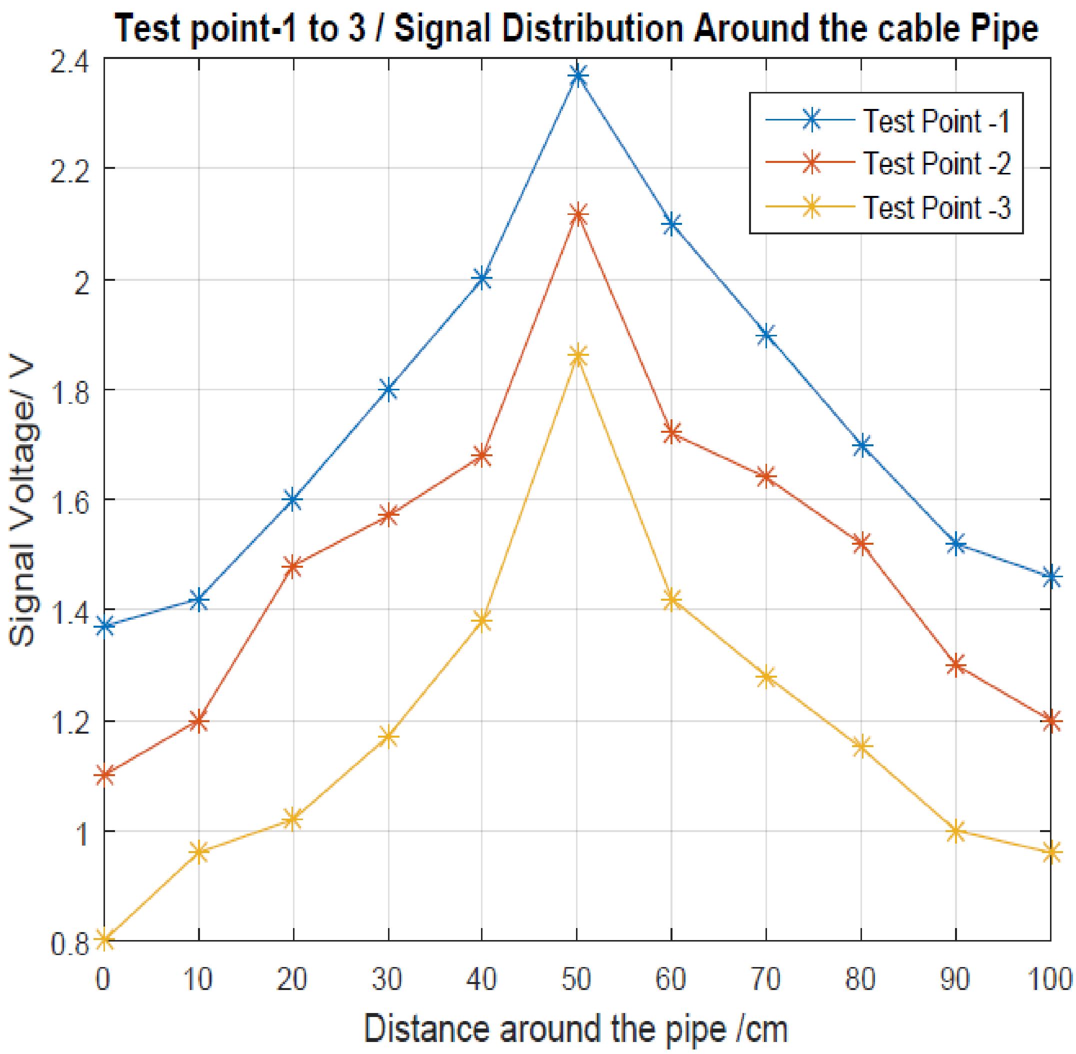

Figure 4.17 Cable pipe line all test points Signal Distribution

4.4.5. Cable pipe line results - on top of the pipe line

Figure 4.18 presents the signal distribution on top of the pipe line. It was implemented negative gradient line due to attenuation of the points by soil and pipe depth. Gradient between the first and second point is

$$gradient(m) = \frac{2.37-2.12}{1-2} = -0.25 \tag{6}$$

However, Figure 4.14 40mm/1000 cable carrying PVC system test point -1- 50 cm position result and Figure 4.7 test point-1 50cm position result had some difference because of the soil condition and depth. 40mm/1000 cable carrying PVC was deeper than the 20mm/1000 water pipe. Also inside of the PVC carriers were different. So that vibration propagation had been behaved different manner.

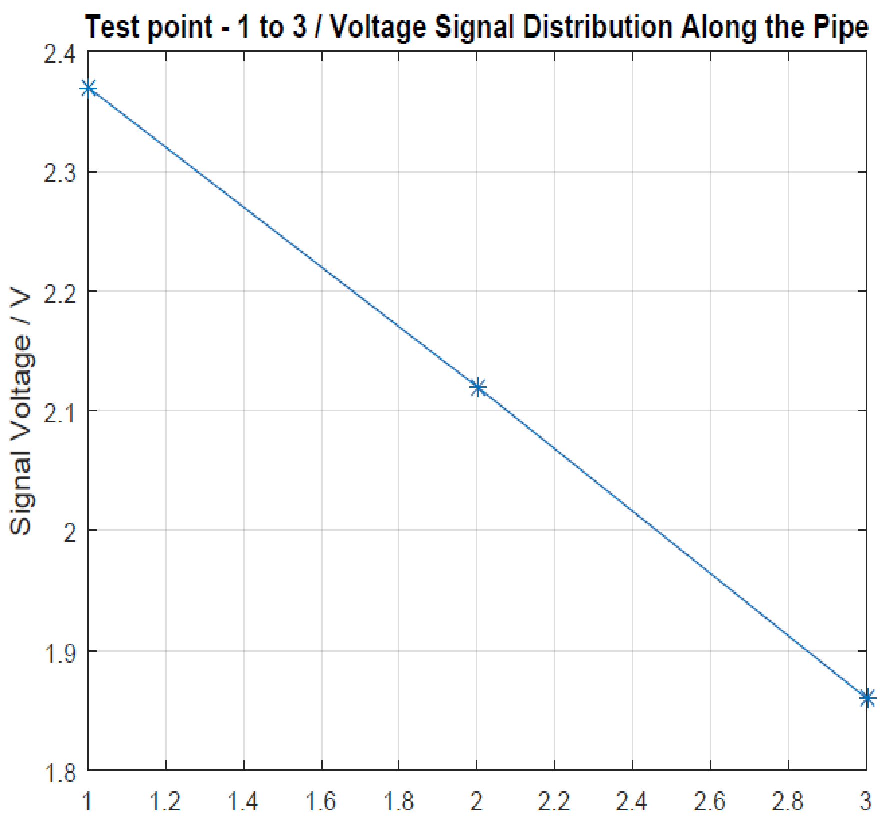

Figure 4.18 Cable pipe line along the Signal Distribution

4.5. 30mm/1000 PVC water pipe testing

In this test, consider the 30mm/1000 PVC water pipe which is laied accoding to the below Figure 4.19. The field of the bellow figure is shown which locating three testing points, those are on top of the pipe line. Distance between the first and second test point is 10m and second and third one is 13m.First and Third test points near to the ground line but second one had a considerable depth.

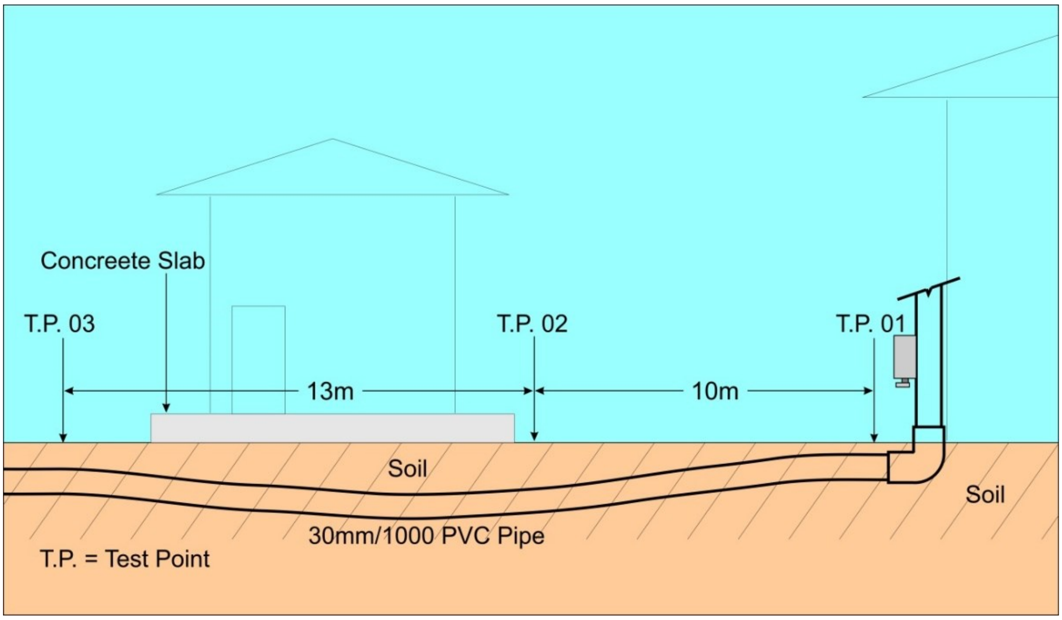

Figure 4.19 30mm/1000 PVC Measurement area setting out

4.5.1. 30mm/1000 PVC result - on top of the pipe line

According to the Figure 4.19 there are three test points. Figure 4.20 shows the results graph of that test points. First and third test point's signal levels are higher than the second one because of the depth of the pipe and soil density around the pipe line which is represent the vibration signal attenuation or damping as well soil condition like loose, pack, wet, dry etc.

According to the equation (2) signal voltage should decrease because of its inverse exponential value. However, Figure 4.12, Figure 4.18 and Figure 4.20 signals distribution along the pipeline is clearly represent. So these three types of results proves the equation (2) behavior and vice versa.

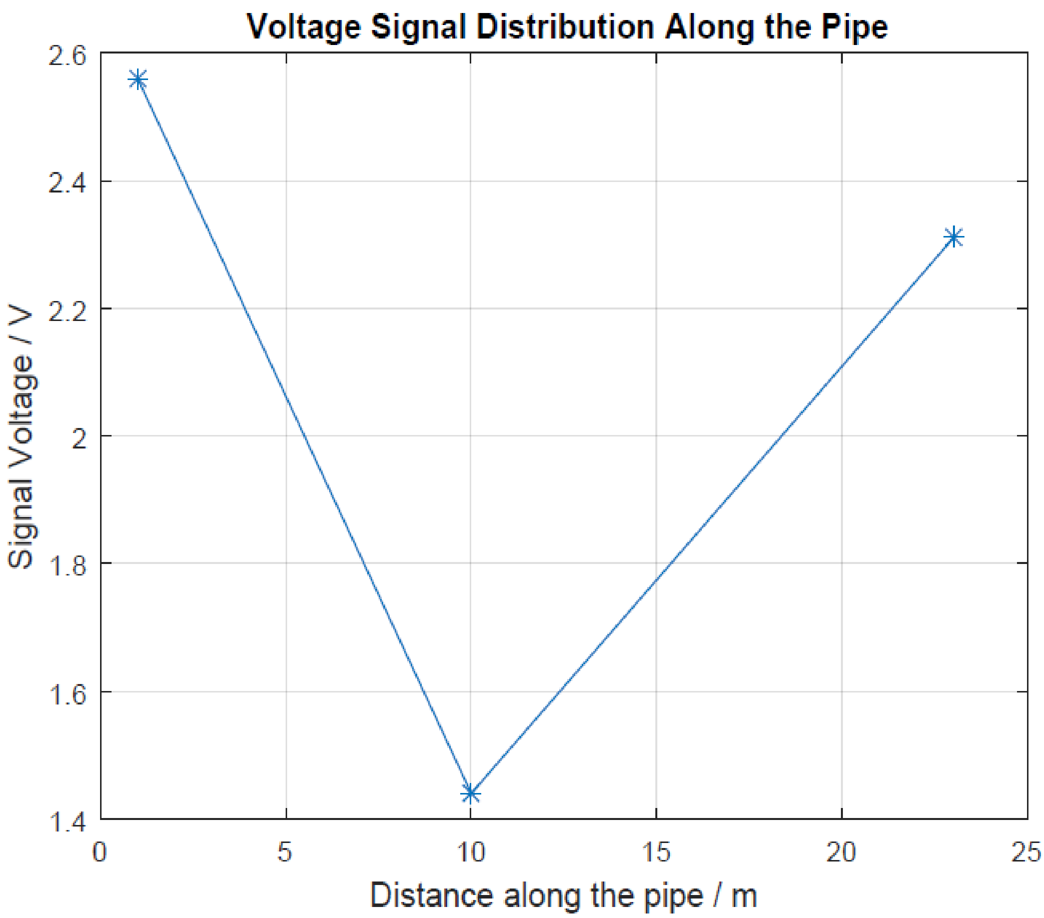

Figure 4.20 30mm/1000 PVC result - Along the pipeline

CHAPTER V

5. CONCLUSION

The underground PVC /PE water pipe detection system has used to acoustic signal for identification of buried PVC/PE pipes. The results of the system totally depend on the distance between acoustic generator and sound pick up device and soil conditions.

The vicinity of the buried pipeline depends on the signal absorption and attenuation. It was observed that the characteristic of the soil such as loose soil, pack soil and water contain of the soil were main conditions when seeking the buried pipelines because it changes the vibration penetration.

When looking through the three test setups, voltages on the pipeline were slightly decay so vibration propagation through the pipeline might be significant result and propagation distance through the pipeline might be lengthy.

According to the result of the signal voltages through the pipeline and vicinity of the pipe line, the acoustic system was shown as a technically suitable and inexpensive method to find the underground PVC/PE pipeline.

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APPENDIX A: SPECIFICATIONS AND CODING

A1.1 Precision Instrumentation Amplifier AD524

FEATURES

Low noise	: 0.3 μV p-p at 0.1 Hz to 10 Hz
Low nonlinearity	: 0.003% (G = 1)
High CMRR	: 120 dB (G = 1000)
Low offset voltage	: 50 μV Low offset
Voltage drift	: 0.5 μV/°C
Gain bandwidth product	: 25 MHz

- Pin programmable gains of 1, 10, 100, 1000
- Input protection, power-on/power-off
- No external components required
- Internally compensated
- MIL-STD-883B and chips available
- 16-lead ceramic DIP and SOIC packages and 20-terminal leadless chip carrier available
- Available in tape and reel in accordance with EIA-481A standard
- Standard military drawing also available

GENERAL DESCRIPTION

The AD524 is a precision monolithic instrumentation amplifier designed for data acquisition applications requiring high accuracy under worst-case operating conditions. An outstanding combination of high linearity, high common-mode rejection, low offset voltage drift, and low noise makes the AD524 suitable for use in many data acquisition systems.

The AD524 has an output offset voltage drift of less than 25 μV/°C, input offset voltage drift of less than 0.5 μV/°C, CMR above 90 dB at unity gain (120 dB at G = 1000), and maximum nonlinearity of 0.003% at G = 1. In addition to the outstanding dc specifications, the AD524 also has a 25 kHz bandwidth (G = 1000). To make it suitable for high speed data acquisition systems, the AD524 has an output slew rate of 5 V/μs and settles in 15 μs to 0.01% for gains of 1 to 100.

As a complete amplifier, the AD524 does not require any external components for fixed gains of 1, 10, 100 and 1000. For other gain settings between 1 and 1000, only a single resistor is required. The AD524 input is fully protected for both powers-on and power-off fault conditions.

The AD524 IC instrumentation amplifier is available in four different versions of accuracy and operating temperature range. The economical A grade, the low drift B grade, and lower drift, higher linearity C grade are specified from −25°C to +85°C. The S grade guarantees performance to specification over the extended temperature range −55°C to +125°C. The AD524 is available in a 16-lead ceramic DIP, 16-lead SBDIP, 16-lead SOIC wide packages, and 20-terminal leadless chip carrier.

PRODUCT HIGHLIGHTS

1. The AD524 has guaranteed low offset voltage, offset voltage drift, and low noise for precision high gain applications.
2. The AD524 is functionally complete with pin programmable gains of 1, 10, 100, and 1000, and single resistor programmable for any gain.
3. Input and output offset nulling terminals are provided for very high precision applications and to minimize offset voltage changes in gain ranging applications.
4. The AD524 is input protected for both power-on and power-off fault conditions.
5. The AD524 offers superior dynamic performance with a gain bandwidth product of 25 MHz, full power response of 75 kHz and a settling time of 15 μs to 0.01% of a 20 V step (G = 100)

A1.2 Microprocessor Programmable Universal Active Filters (MAX260/MAX261/MAX262)

The MAX260/MAX261/MAX262 CMOS dual second order universal switched-capacitor active filters allow microprocessor control of precise filter functions. No external components are required for a variety of band pass, low pass, high pass, notch, and all pass configurations. Each device contains two second-order filter sections that place center frequency, Q, and filter operating mode under programmed control. An input clock, along with a 6-bit f0 program input, determine the filter's center or corner frequency without affecting other filter parameters. The filter Q is also programmed independently. Separate clock inputs for each filter section operate with a crystal, RC network, or external clock generator. The MAX260 has offset and DC specifications superior to the MAX261 and MAX262 and a center frequency (f0) range of 7.5 kHz. The MAX261 handles center frequencies to 57 kHz, while the MAX262 extends the center frequency range to 140 kHz by employing lower clock-to-f0 ratios. All devices are available in 24-pin DIP and small outline packages in commercial, extended, and military temperature ranges.

FEATURES

- Filter Design Software Available
- Microprocessor Interface
- 64-Step Center Frequency Control
- 128-Step Q Control
- Independent Q and f0 Programming
- Guaranteed Clock to f0 Ratio-1% (A grade)
- 75kHz f0 Range (MAX262)
- Single +5V and ±5V Operation

A1.3 Arduino DUE Technical Specification

Microcontroller	AT91SAM3X8E
Operating Voltage	3.3V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54(of Which 16 Provide PWM output)
Analog Input Pins	12
Analog Output Pins	2(DAC)
Total DC Output Current on all I/O lines	130mA
DC Current for 3.3V Pin	800mA
DC Current for 5V Pin	theoretical 1A, realistic 800mA
Flash Memory	512KB all available for the user applications
SRAM	96KB (64+32KB)
Data Flash	2 Mbit (250KB)
Clock Speed	84MHz

A1.4 Instantel Micromate Specification

Tri axial geophone

Table 5-1 Tri axial geophone Specification

Range	Up to 254 mm/s (10 in/s)
Response Standard	ISEE Seismograph Specification or DIN 45669-1
Resolution	0.00788 mm/s (0.00031 in/s)
Frequency Range (ISEE/DIN)	2 to 250 Hz, within zero to -3 dB of an ideal flat response / 1 to 315 Hz
Accuracy (ISEE/DIN)	+/- 5% or 0.5 mm/s (0.02 in/s), whichever is larger, between 4 and 125 Hz / DIN 45669-1 Standard
Transducer Density	2.2 g/cc (137 lbs/ft^3)
Maximum Cable Length (ISEE/DIN)	1,000 m (3,250 ft.)