# Application of Spread Spectrum Time Domain Reflectometry for ADSL Fault Detection

BY: GIRMA TESHOME

ADVISER: EPHREM TESHALE (PhD)

A thesis submitted to School of Electrical and Computer Engineering

Addis Ababa Institute of Technology

In Partial Fulfillment of the Requirements for the Degree of Master of Science

(In Communication Engineering)

Addis Ababa University

Addis Ababa, Ethiopia

May, 2021

## DECLARATION

I, the undersigned, declare that this thesis comprises my own work in compliance with internationally accepted practices; I have fully acknowledged and referred all materials used in this thesis work.

Girma Teshome

Name

Signature

**Addis Ababa University**

**Addis Ababa Institute of Technology**

**School of Electrical and Computer Engineering**

This is to certify that the thesis prepared by **Girma Teshome**, entitled *Application of Spread Spectrum Time Domain Reflectometry for ADSL Fault Detection* and submitted in partial fulfillment of the requirements for the degree of Master of Science (communication Engineering) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee

| | | | | | |
|---|---|---|---|---|---|
| Examiner-1 | Dr. Yalemzewd Negash | Signature | ____________ | date | ________ |
| External-2 | Dr. Yihenew Wondie | Signature | ____________ | date | ________ |
| Advisor | Dr. Ephrem Teshale | Signature | ____________ | date | ________ |

______________________________________________

Dean, School of Electrical and Computer Engineering

# ABSTRACT

The tremendous increase of interest in an increasingly expanding online world, access service providers face many unique challenges. Each and every subscriber are consistently demand more bandwidth to access video, gaming, and other online content at the same time multiple users demanding consistent performance from the fixed access network.

To have more efficient ADSL technology, it wants to trace faulty points to avoid or reduce a loss so that a convenient technique has to be implemented. In copper cable communication, Time domain reflectometry or “Megger” technique was commonly used for characterization and fault location of copper cable transmission systems. TDR measures averaging so lacks accuracy in fault detection and a fault characterization will be done by low voltage, low impedance and echo based analysis. In TDR the analysis detection can be only suitable in short distance due to narrow pulse. ADSL line fault can be detected using TDR when the reflected signal generated due to impedance mismatch and electromagnetic discontinuity.

Since fault detection using the classical Time Domain Reflectometry for ADSL technology is vulnerable for different noise, which results attenuation to locate the faulty point accurately. To overcome such problem, these study will implement distributed (SSTDR) fault detection means. Previously different researchers were analyzed and used this fault detection method in order to overcome fault location problem and to enhancing accuracy within a minimal power threshold. Distributed SSTDR fault detection means have been implemented as an operative fault detection technology aimed at finding distorted fault points on aircraft wires.

The optimization and fault detection for ADSL technology is done using correlation algorithm by analyzing and correlating the incident signal with reflected signal with bigger bandwidth and kasami sequence generator was used in the simulation and modulated with sine wave and spreaded over the transmission line and despreaded before cross correlation is done. Incident signal and reflected signal is analyzed using correlation function and the maximum peak will determine the fault status and its location. Finally, different form of fault sparked and the fault determined based on the reflected signals. Basic verification parameters are power, signal to noise ratio and distance. This research shows a progress in locating a defect point compared to the classic TDR fault detection techniques for ADSL technology.



**KEYWORDS**

ADSL, TDR, SSTDR, Reflectometry, Spread Spectrum

# ACKNOWLEDGEMENTS

First and foremost, I would like to give special thanks and glory to the Omnipotent, Omnipresent, and the Omniscient Almighty God who is the wonderful source of my strength. He gave me the grace, Wisdom, good health and guided me in all the ways of my life. I would like to express my deep and sincere gratitude to my adviser Dr. EphremTeshale for his academically essential guidance, hints, motivation, ideas, support and valuable comments over the course of my thesis research. Throughout my thesis work, I have received so much help from him and completing this thesis work would have been all the most difficult without his support. My special thanks also goes to my wife for the love, care and encouragement you have bestowed upon me, through thick and thin. Thank you for the constant encouragement during all these years.

Thank you ALL!!!

Addis Ababa, May, 2021

Girma Teshome

# ACRONYMS

| | |
|---|---|
| **SS-TDR** | Spread Spectrum Time Domain Reflectometry |
| **ADSL** | Asymmetric Digital Subscriber Line |
| **DSL** | Digital Subscriber Line |
| **DMT** | Discrete Multi-Tone |
| **CO** | Central Office |
| **LMDS** | Local Multipoint Distribution Service |
| **BWA** | Broadband wireless access |
| **PCI** | Peripheral Component Interconnect |
| **USB** | Universal Serial Bus |
| **x-DSL** | x Digital Subscriber Line (of any type) |
| **CAD** | Computer Aided Design |
| **FEC-** | Forward Error Correction |
| **RFL** | Resistive Fault Location |
| **FDM** | Frequency Division Multiplexing |
| **MIMO** | Multiple-Input Multiple Output |
| **DSL** | Digital subscriber line. |
| **DSLAM** | Digital-Subscriber-Line-Access Multiplexer, |
| **CPE** | Customer Premises Equipment |

| | |
|---|---|
| **Mbps** | Megabits per seconds |
| **WiMAX** | Worldwide Interoperability for Microwave Access |
| **QoS** | Quality of Services |
| **PSTN** | Public Switched Telephone Network |
| **FWA** | Fixed Wireless Access |
| **3GPP** | Third generation partnership project |
| **IEEE** | Institute of Electrical and Electronics Engineer |
| **PRBS** | Pseudo-Random Binary Sequences |
| **ACR** | Autocorrelation |
| **CCR** | Cross-correlation |
| **RLS** | Recursive Linear Signal |

**CONTENTS** **page No.**

## LIST OF FIGURES

---

LIST OF TABLES

1

# CHAPTER ONE: INTRODUCTION

## 1.1 INTRODUCTION

Now a day’s household Internet users are looking higher bandwidth to entertain gaming, video, and online contents. Likewise, different service is consistently increasing with attractive offers and service to swap customers [1]. In the current telecommunication networks, telecom network operators and service providers are responsible for providing a service as per the customer subscriptions with a better efficiency and quality but there are a lot of challenges to deliver the desired service because:

(i) Some of the network element deployed is very deteriorated and too old. The technical and operational section are not rehabilitating the entire network as per the standard periodically. Hence the nature of the technology by itself has a tendency to drop a data due to long distance and redundancy of joints.

(ii) The redundancy of fault occurrence is also a great factor for service providers to proactively maintain the network.

(iii) Unable to locate the defect in automated manner due to the fault detection mechanism used was not effective and efficient relative to all alternative transmission line fault detection technique.

On the other hand, in current copper networks, both the customer premises equipment(CPE) and network elements are nearly located from 2-2.6 miles far and this will lead to a decrease in the subscribed service.

When incident or fault occurred obviously the efficiency and quality of the service will be very less. In order to overcome such problems and defects, improving a fault detection technique will lead the service provider to be highly reactive to any kind of faults and incidents.

In principle a network needs to be controllable and accessible. As the complexity of network deployments increases, the number of devices deployed increases as well. Manual configuration and fault detection of such devices is error-prone and time-consuming. As a consequence, one expectation of future networks is to provide mechanisms to the operators to simplify network management, reduce the amount of time needed to configure devices, minimize configuration errors and upgrading a convenient and reliable fault detection mechanism is important activities.

Networks of the next generation need to be flexible and dynamic to accommodate the expected demand. For instance, as per Cisco visual networking index, the entire IP traffic will increase at a Compound Annual Growth Rate (CAGR) of 24% from 2016 to 2021 [2]. On peak hour Internet traffic will enhance by 4 to 4.6 factor from 2016 to 2022, whereas previous average traffic was up to 3.2 before 2016 and mobile phone traffic will exceed fixed line technology by 2021. Where the data load could reach 3.3 ZB per year (ZB; 1000 Exabyte [EB]), or 278 EB per month. It clearly shows that; networks need to provide sufficient bandwidth to transfer such huge amounts of data. However, they also need to be dynamic and flexible so that data transfers can be initiated when needed. Therefore, to accommodate this competition and user demand service provider should proactively enhance fault detection techniques specifically ADSL broad-band service provider should look forward in finding intensive fault detection tools.

A fault detection technique called Spread Spectrum Time Domain Reflectometry(SSTDR) is an emerging and recent fault detection mechanism with a great potential to trace any discontinuity, short and open fault using a correlation function [4]. Ideally, the test signal has more noise resistance performance, if the fault located accurately on different fixed line transmission cable. Previously from different research perspective distributed means of fault detection has been proven as an effective technique to find faults.

Even though SSTDR is mature enough to be implement as a fault detection in areas like high tension power transmission lines particularly in underground cable and in aircraft transmission line and has been shown a better reliability, performance, and location accuracy. One of the common problems associated with imple-mentation is its algorithm complexity especially in fixed communication channel, since it requires adoption of different algorithm.

## 1.2 LITRATURE REVIEW

This section contains a brief discussion of the relevant studies related to the SSTDR fault detection techniques for Asymmetric Digital Subscriber Line Technology. The primary emphasis of the work presented in this research was on the detection of accurate fault location and identifying the status of the fault to enhance signal quality, fault location accuracy and reducing interference.

In [8] Stefan Schuet ; Doğan Timucin ; Kevin Wheeler investigated as TDR- is one of the standard methods for troubleshooting faults in electrical wiring and network topology, Through established hardware tools for experimental purposes. While this portable hardware device built from laboratory assist to determine permanent faults such as open or short and its resistance sensitivity remains a question. This study finds a combined framework for TDR-based resistance fault detection in lossy cables by involving an S-parameter-based modeling methodology with a probabilistic (Bayesian) inference algorithm.

From Enhanced Resolution TDR for High Speed Channels fault characterization: Characterizing Spatial Discontinuities with Non-Ideal Stimulus article [9] Suvadep Banerje, Hyun Woo Choi. Keezer and Abhijit Chatterjee stated in the recent past, there has been stable growth in the data transfer rate of modern digital sequential communication systems. Therefore, precise explanation of accelerated signal on a transmission lines is very important for ensuring high signal reliability. Time and frequency based Reflectometry method has been widely used in previous research to determine high speed communication. The completeness of the fault classification depends on the sampling execution rate of the TDR input signal [9].

At high speeds it is not always thinkable to deliver a perfect impulse in TDR fault detection technique. In [8], an algorithm is replaced for the natural attenuation in real identified attenuation reflectometry injection to increase the accuracy of interconnected characterization. The proposed algorithm is applied to the problem of micro strip transmission line characterization for identifying attenuation in signal interconnect.

Similarly On their article[10] P. Smith ; C. Furse ; J. Gunther carried out in many cases SSTDR and series time domain reflectometry have been shown to be operative technologies in finding faults on aircraft wires carrying typical signals during flight. This paper studies the parameters that control the accuracy, latency, and signal to noise ratio for these technique.

Setting for TDR modular in digital communication analyzer, Lu Fumin Shanghai Institute of Measurement and Testing Technology, Shanghai, 2012, Impedance discrepancy of signal transmission paths can cause signal reflection, decrease the signal quality, so the impedance in the signal transmission paths desires to be understood and controlled. During impedance measurements, the preferred method is TDR, which uses high performance digital communication analyzer equipped with TDR modules. But so far, relevant verification regulation and calibration specification of TDR module has not issued by the institute so far [19].

Even though the issue of fault detection in ADSL and the use of SSTDR have been investigated thoroughly independently, to the best of the author's knowledge there has not been substantial effort to investigate the performance of SSTDR as applied for fault detection in the context of ADSL cables. After reviewing most relevant works, we propose the application of SSTDR fault detection techniques with high peak correlation algorithm and channel conditions which can be verified by the power usage, signal to noise ratio and by minimal error rate. Throughout these theses Spread Spectrum Technology was applied on the existing classical TDR fault detection techniques. Four fundamental verification parameters identified and comparison work is done.

## 1.3 STATETMENT OF THE PROBLEM

Intention is on fault detection because now a day's usage of fixed line Broadband Internet is extremely increasing across the world. Hence digital subscriber line using wired transmission line is a very convenient and secured platform and it needs to enhance its fault detection techniques.

So far the actual problem faced in ADSL technology is the way each and every fault can be detected and analyzed to satisfy user since the nature of the transmission line are wired and the channel may suffer physical damage which will request inspection and found in unknown location which may tackle data rate at the customer premises (ADSL- modem). So far a classic fault detection called TDR were used.

TDRs method are used for testing cable where they are able to trace and detect faults. As a result, the technique is widely used in any area where there may be long distance of cable that may require to be tested, or they may have defects and faults. It is also a measurement approach to determine the electrical wire or cable characteristics by injecting certain waveforms usually step or impulse signals and observing reflected waveforms. This classical fault detection technique compares the reflections from the unknown line environment to those generated by standard or given impedance.

Nowadays, ADSL technology has an application for different purpose but the performance is decreasing from time to time due to lack of accuracy on detecting fault location because ADSL technology is exposed for interference and other impairments that make the channel unpredictable. In today's wired networks, there is an increasing demand for service quality, high data rates, network coverage, and lesser processing time. The scarcity of two fundamental resources for communications, namely, energy and bandwidth, is a serious challenge to fulfill these demands. To achieve high service quality, high data rate, network coverage and lesser processing time a lot of obstacles exist which is caused by:

- Impedance sensitivity
- Unable to detect cable fault and its location
- High power flux density
- Affected easily by various noise and interference
- Energy and bandwidth constraint
- Other impairments that make the channel unstable

Here in this thesis, a strong attention is given on the problem arrived because of fault detection problem. Faults of ADSL cable affects the performance of wired network. As a result, here, to overcome the problem, the use of SSTDR fault detection technique is proposed as an alternative means of alleviating the problem arrived because of fault detection error.

Providing an alternative fault detection mechanism for ADSL technology in a very convenient and reliable manner by investigating the best type of fault detection mechanism from previously experienced classical TDR and spread spectrum detection mechanism and its significance over the existing fault detection mechanism. Basically, this thesis will try to answer:

- Why ADSL fault detection and why SSTDR fault detection mechanism is preferred?
- How the fault detection work using SSTDR particularly for ADSL technology?

## 1.4 OBJECTIVE

### *1.4.1 General Objective*

The general objective of this thesis is to study and analyze the application of SSTDR fault detection technique in ADSL technology.

### *1.4.2 Specific Objective*

Specifically, it aims to:

a. Undertaking analysis on application of SSTDR fault detection for ADSL technology.
b. SSTDR system modelling based on compatibility with ADSL transmission line.
c. Performance analysis to determine the feasibility and efficiency of SSTDR relative to classic TDR.
d. Comparing SSTDR technique from the previous fault detection mechanism of ADSL technology.
e. To increase reliability of fault detection technique for ADSL broadband customer.
f. Providing a proactive solution for ADSL broadband users by developing a model and corresponding Simulations analysis.

## 1.5 METHODOLOGY

### *1.5.1 General Approach*

| Methodology | Simulation tools | Elements to be tested/Experimented |
|---|---|---|
| Perform hand calculations and simulations | MATLAB Software | Faulty point or nodes of cables |

Table 1-1 Research methodology & tools used

The methods used to achieve the desired objectives of this thesis were as follows. First, literature reviews about TDR and spread spectrum were conducted. Second, we combined both classic TDR and spread spectrum and modeled the system, and then we programmed the system in MATHLAB 7.0 software as a simulation tool. Finally, the results were interpreted and conclusion was drawn based on the results obtained.

### *1.5.2 Literature Review*

Literatures such as books, journals, magazines, Internet sources and others are referred regarding the concept and the researches made on fault detection in broadband networking technology. Also other papers that have direct or indirect relation to this work are reviewed. The research gap is identified and formulated a refined research goal. The knowledge is grasped about the study area of the topic which is going to be researched and learned from previous works done by other researchers in the area.

### *1.5.3 Modeling and Experimental Techniques*

For this study Matlab 7.0 is used to analyze and model fault detection topology algorithms.

### *1.5.4 Test and Evaluation Techniques*

Analysis and evaluation is appropriate and important in order to assess the output of the study. Analysis and interpretation of the results and outcomes of the thesis was stated. Tools like MATLAB will be mainly used in this thesis for simulation and modelling purposes.

The so called Megger tester or classic TDR device is an essential device to perform this research in order to calibrate different values of ADSL parameters using the TDR by incorporating spread spectrum technique.

**Performance comparison;** Includes comparing the performance of the previous classical TDR fault detection techniques with distributed SSTTDR technique. Comparison and verification parameter are power or energy used, signal to noise ratio and error detection rate with their respective distance of fault locations.

**Methods/Statistical analysis:** A study was conducted at loose or faulty connection state below the reference threshold value, the poor and bad contact fault generated between the cable and the connection terminals was measured using the SSTDR techniques to detect the failure. The accuracy of the reflected signal detection was done by applying a correlation algorithm on the incident and reflected signal.

## 1.6 Scope and Limitation

### *1.6.1 scope of the study*

It is known that nowadays the demand of digital technology is accelerating in different platform, from applications to network communication. With the increasing demand for high bandwidth network traffic that is expected from technologies like Artificial Intelligence (AI) and Internet of Things (IoT), enterprises will need huge amount of interconnection bandwidth to function properly. This amount of traffic will require a more scalable, reliable and dynamic network model and fault detection techniques. All entity of broadband internet user requires to get a consistent and quality based access without any distortion and interruption. Any connected entity and service user shall get proactive fault detection mechanism designed to allow all broadband users to stay connected anywhere any time with fast connectivity to all of the necessary applications.

Adopting SSTDR fault detection techniques in ADSL broadband technology is a new trend like that of OTDR for fiber optics. It’s expected to provide accurate fault location and enhance SNR while comparing with the previous classical fault detection technique called TDR. The current fault detection technique of the copper or twisted pair cable network which can be used to make optimal decisions for fault location, unlike TDR which is based on impedance mismatch decisions made by discontinuity node.

In general, the scope of this study is analyzing the application of SSTDR method for ADSL digital technology, modelling and comparing with the existing classical TDR fault detection method.

### *1.6.2 Limitation of the Study*

The system model in this study considered the main optimizer and detection analysis could likely have performed to trace each incident and corresponding reflected signal with delay. However, the below stated limitation and challenges are main drawbacks of the thesis.

- It is difficult to model directional coupler in the simulation particularly in copper cable family.
- Difficult to study in many sequences generator type due to their variable characteristics.
- Uncertainty on propagation speed ($v_p$) results variation on some reflection points
- Requires algorithm and makes it complex compared to the previous classic TDR fault detection technique.
- Difficult to identify intermittent or fault caused by noise, since soft faults are challenging to be traced.

## *1.7 Contributions of the Research*

At the end of this research, the result will have both practical and theoretical significance. The increase of demand in broadband internet service using ADSL technology will be convenient in terms of fault detection to enhance data rate and SNR with minimal threshold parameters such as big data, Internet of Things (IoT) and cloud services fundamentally change the way we store, acquire and transfer information and data. Accompanied with these new fault detection techniques in wired communication channel trends, telecom operators are facing challenges in transmission line fault detection and to identify the status of the channel to acquire a better signal or data rate and SNR at far end of the modem by troubleshooting the transmission line, resource utilization, and high-speed transmission. To tackle these challenges, telecom operators like ethiotelecom need to use this emerging fault detection technique for ADSL modem Transmission line.

This study enables all digital Broad band internet service provider to have an insight of how the company can adopt SSTDR fault detection techniques on its own local and virtual networks. It also indicates and explores the suitable algorithm and model that can be used to analyze SSTDR fault detection techniques using correlation algorithm and function adopt with defined parameters. This research also could be the opening point to conduct researches in ISP for ADSL broadband communication cable. The study operates using compatible algorithms and with suitable parameters for ADSL technology and equipment's.

All stated parameters are based on the characteristics of ADSL Technology and the study considered all possible characteristics of ADSL. It could be used as a reference for further researches in the area and make it available for academic reference.

## *1.8 Organization of the Thesis*

The work of this thesis is organized in to six chapters. Chapter one deals with introduction of the whole. It clearly cites statement of the problem, objective of the study, related works, scopes and limitation of the thesis and the methods how this paper will achieve its objective. Chapter two covers the general fixed line transmission technology implementation, arrangements and characteristics. Chapter three presents SSTDR and classic TDR analysis, manipulation and performance metrics. chapter four presents parameters that are used in ADSL modem fault detection techniques, algorithms and optimization model in detail. Every performance indexes that are used for analysis are presented here in detail. Chapter five focuses on optimization of the models using Matlab based Simulink tool. This chapter also presents analysis and result parts. The last chapter six covered conclusions and recommendations from this study

2

# CHAPTER TWO: FIXED LINE BROADBAND TECHNOLOGY

As a result of this ever changing environment, service provider must implement cost-effective strategies to anticipate problems and to address issues before the consumer is aware of them. All service provider needs to proactively restore effectively to the subscriber before complain register from customer [1]. Addressing these challenges is very though, especially when the question unable to get equivalent solution, therefore, fault troubleshooting, location accuracy and restoration must be in time bound accurately, regardless of network element type and CPE vendor type. The access service providers' last or first mile is by the far the most geographically distributed and most expensive to maintain segment of the broadband network infrastructure [2].

Based on Committee on Broadband Technology, definition of broadband is: the access link performance should not be the limiting factor in a user's capability for running today's applications. In general, any connection to the customer with more than 256 kbps (0.256Mbit/s) is considered broadband Internet [2]. However, there is no specific bitrate defined by the industry until now for Broadband technology.

Broadband is evolving and what we thought in the near past as broadband now has become narrowband mainly due to rapid technological innovations, convergence and increased customer's demands for high bandwidth services [2].

Basically, broadband implementations and characterization are two types, Namely, that consist of ***fixed line*** and wireless broadband implementation. Components in the fixed line broadband and wireless broad band implementations are:

## 2.1 Digital Subscriber Line

**Digital Subscriber Line *(DSL)*:** digital data transmission over the wires used in the local loop of a telephone network Cable modem. designed to modulate a data signal over cable television infrastructure Power line communication [2]. DSL technology consists various types of technology based on their characteristic from this technique ADSL is one of the prominent technology.

## 2.2 Worldwide Interoperability for Microwave Access

**WiMAX:** is a standards based wireless technology that provides high bandwidth broadband connections over long distances [2]. Even though wireless broadband implementations are being emphasized strongly in this competitive world, but the role of fixed line broadband service still cannot be neglected especially x-DSL and cable modem or CPE. They are still widely deployed all over the world. Various Modeling were implemented to monitor the performance of telecommunication networks. There are a lot of parameters that can be considered when performance analysis is done, but this study will only focus on the defect of fixed line transmission cable.

## 2.3 Asymmetric digital subscriber line (ADSL)

**ADSL** :Stands for Asymmetric Digital Subscriber Line and it is a type of DSL Broadband Internet connection platform. One of its great achievements is more quantity of data over telephone lines. They depict an advanced form of traditional modem lines. The hunger of the end-users for fast surfing speed of internet has led to many inventions in this modern time. ADSL modem is a perfect example to represent one of those inventions. ADSL has a particular filter connected to the end user's telephone line which enables both ADSL and genuine telephone services to be run in synchronization. This special filter is called ***micro filter*** [1,3]. For x-DSL technologies, ADSL become essential topic which will be discussed and analyzed in terms of the insulation technique [3].

Asymmetric Digital Subscriber Line technology is one of the most well established DSL technologies for high speed communication access capability for various services over the twisted-pair cable infrastructure [3]. The performance of x-DSL technology is affected mainly by two factors, which are condition of the loop and transmission signal affected by environment. There are also other factors include attenuation, return loss, split pairs, wire gauges and interruption.

An unbalanced circuit caused by unbalanced currents or power line harmonics can cause crosstalk noise, causing bit errors that result in slower x-DSL transmissions signal and thus reduce the efficiency and performance of x-DSL services. By using different wire gauges in a single cable can also result in impedance mismatch which can affect the efficiency of delivery [4]. The factors stated above are only related to the characteristics of physical layer that can directly influence ADSL modem. In fact, the modulation scheme, forward error scheme in upper layers for the system will also affect the performance.

The distance between each network element and subscriber should be in a radius of maximum 2.5 miles. ADSL modem has upstream rate of 16 to 64 Kbps and its downstream rate is 1.5 to 9 Mbps which makes it preferable over all the other connections available in end user's close proximity [5].

ADSL modem has three type basic interface. These are ***Ethernet***, ***PCI*** and ***USB***. The main advantage of ADSL modems that it can easily create multiple channels in order to transfer the data. For this, the ADSL modems divide the bandwidth available in two different ways. These are ***Echo cancellation*** and ***Frequency Division Multiplexing*** (FDM). The Frequency Division Multiplexing(FDM) assigns 1 band for the upstream data while another for downstream data. So, it can be said that in spite of such balanced capabilities of ADSL modem, the internet users who use modems should not be frightened with technological capabilities of modem [4].

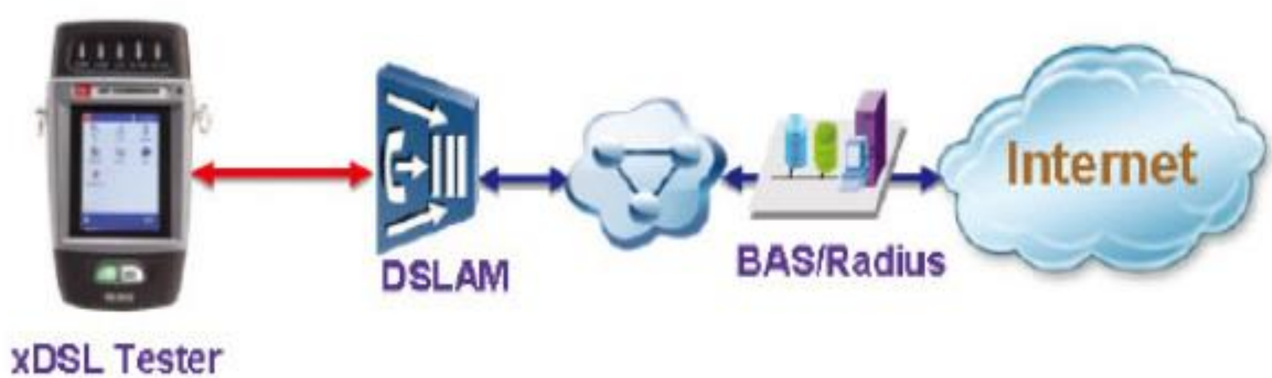



Figure 2-1: ADSL transmission line Detection [4]

## 2.4 Fixed line Transmission cables

### 2.4.1 Electrical cables

Since the development of electrical systems, the use of electrical cables became ancient. Now a day's Electrical cables are widely used in almost all the modern systems, where the energy and information flow from one part to another in the system. We can mention several examples, such as transportation systems, nuclear power plants, industrial machinery, electricity transmission networks, etc. The cable types can vary depending on the nature of the transmitted signals, and the environment in which the cable is placed the transmitted signals can be either analog or digital, have low or high power, at low, medium or high frequencies. The environments vary widely, and cables can be placed in the air or overhead, such as for power transmission networks, also in the sea or in the ground for underwater and underground connections [6].

Another example is computer networks, which may use two different types of cables: coaxial cables and twisted pair. With this increasing use of electrical cables, the length of the wires in some systems have also increased during the past few years. Aircraft and watercraft are examples where the cumulative length of cables might reach several hundred kilometers. The several examples allow to introduce the three most used cable types: coaxial, twisted pair, and power cables [6].

### 2.4.2 Coaxial cables

Coaxial cables provide electrical power using an inner metallic conductor usually a flexible solid copper wire encircled by an insulating sheath layer and all enclosed and protected by a shield layer. The internal conductor core cable is usually protected by an outer insulating jacket or sheath. Normally, the shield will help to carry electrical power to keep its conductivity.

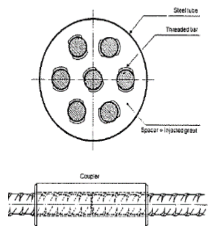
The advantage of coaxial cable design is that the electric and magnetic fields are very limited to the dielectric with minimum leakage and loose outside the jacket shield. Conversely, electric and magnetic fields outside the cable are largely kept from causing interference to signal inside the cable. These characteristics makes coaxial cable a good choice for carrying weak signals that cannot tolerate interference from the environment or for higher power signals that must not be allowed to radiate into adjacent structures or circuits. Very common applications of coaxial cable include video and CATV distribution, RF and microwave transmission, and computer data connections [6,7].

## 2.4.3 Twisted pair

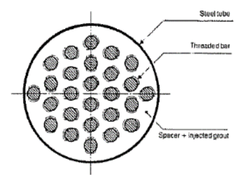
Twisted pair (TP) cabling is a type of fixed network which has two isolated conductors that means the forward and return conductors of a single circuit are twisted together for the purposes of avoiding noise or interference from external sources; for instance, electromagnetic radiation from unshielded twisted pair (UTP) cables, and crosstalk or interference between neighboring pairs. Twisted pair can be categorized in two main categories: Shielded Twisted Pair (STP) and Unshielded Twisted Pair (UTP). In computer networking systems that use twisted-pair cabling, one pair of wires is used for transmitting data while the another pair receives data. Twisted-pair cabling used in Ethernet networking is usually unshielded twisted-pair (UTP) cabling, while shielded twisted-pair (STP) cabling is typically used in Token Ring networks. Considered the case of uniform two wire transmission lines, As the starting point to validate the detection and location of faults. [6]

## *2.4.4 Types of Cable:*

- Parallel-bar cables:→

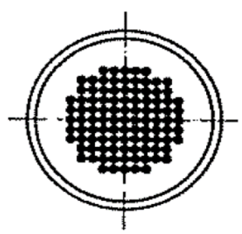


Coupled bars

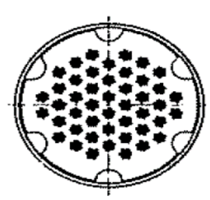


Uncoupled bars

- Parallel-wire cables:→



- Stranded cables:→



- Locked Coil cables:→

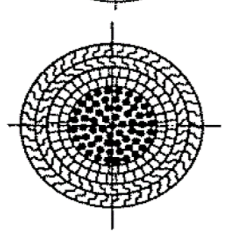
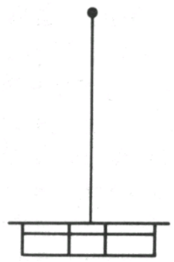


Figure (2-2) type of cable structure [6]

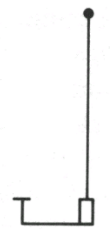
## 2.4.5 Cable arrangements:

**<u>Transverse:</u>**

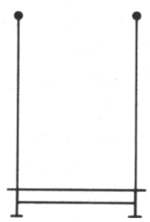
a) Single Plane -Vertical.



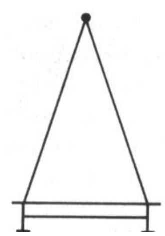
b) Single Plane-Vertical or Lateral.



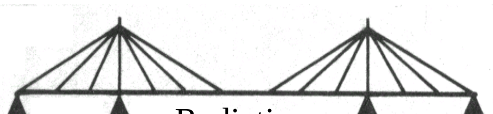
c) Double Plane-Vertical.



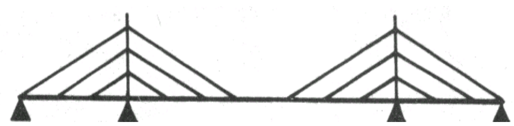
d) Double Plane-Slopping.



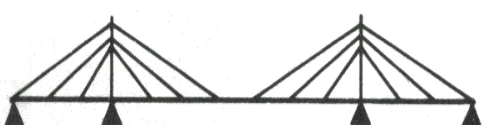
**<u>Longitudinal:</u>**



Radiation



Harp



Fan

Star

Figure (2-3): Cable arrangement [6]

### 2.4.6 Cable Fault Detection, Location and Cable Failure Types

Identifying faults and avoid their effects are key issues when one of the system quality parameters such as availability comes into mind. For many years, fundamental actions, such as the cable progressive cutting based on divide and conquer algorithm to detect the fault location were used. During a long period after that many technical advances were made in this area in order to minimize costs and make shorter the availability interruptions of the system [7]. A faulty state in the system will be affecting to its performance, and its transmission channel status.

When there is a fault in one communication line, usually it is caused by different external aggressions, changing the normal structure of the cable and affecting its behavior. Those aggressions can be caused by a lots of factors such as, bad weather conditions, incorrect manipulation, working machinery without the knowledge of the cables' existence in a working area. The two last faults mentioned sources are very common for underground cables in the post installation process if manipulation or some errors when the cables are being placed have not damage the cable before. Different types of faults can appear based on cable damaged structure:

**Contact fault:** There is enough damage in the insulation that a connection appears between two or more cores. The most critical situation is when there is a short circuit between cores. In an energized cable the result can be an overcurrent and its outcome is short circuit fault.

**Ground contact fault:** Fault when one appears an unwanted connection between a conductor and the mass of earth. Note that again it has to be a lack of insulation in one phase, being the rest of them enough isolated to avoid mutual connections and appearing leaking currents from the faulty phase, which will be following the mass of earth path.

**Break:** Damage in conductors, which can be a little gap in the core or a complete cut, creating an open-circuit situation. This fault sign will be compromising the availability of the communication line if the impedance is high enough and results open circuit fault.

**Ingress of moisture:** Very slight process because of the moisture's tendency to distribute along the cable. It has to be enough damage in the sheath and the plastic film protecting the phases in the cable to allow the ingress of moisture. The spreading process over the cable cannot be defined beforehand because it depends on the quantity of moisture penetrating and the cable's position. If there is some additional damage in the cores' insulation, it can derive in one of the two first types of faults.

**Transitory:** They used to be in Low voltage(LV) networks. A typical scenario is a blown fuse, the replacement of the fuse and a normal performance of the system again. This means one of the most important characteristics of faults in the distribution networks and it is the coexistence during long periods with a normal behavior of the system. It is not fault by itself but will effect on core-to-core or core-to-ground faults, which can be producing arcing and voltage distortion [7].

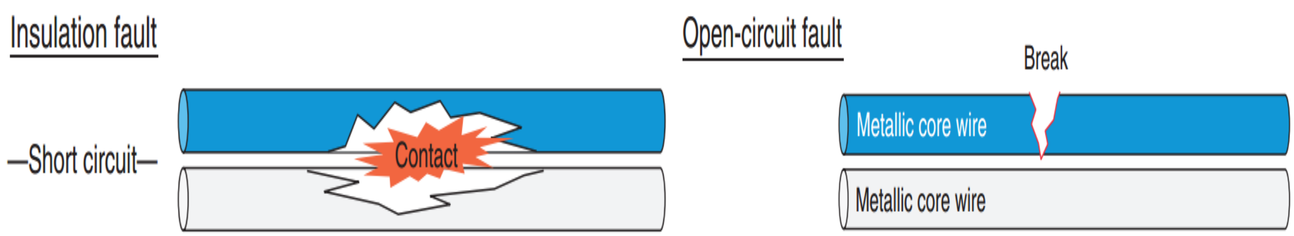



Fig2-3: Insulation and Core-wire fault [7]

### 2.4.7 Fault stages

There are four basic fault stage that can affects the performance of the transmission systems or cables, as it can be seen below.

**Dormant:** The sheath and the protection have been damaged and there is not a complete protection avoiding the entrance of impurities. Line performance can be subject to the quantity and composition of any foreign component coming into the cable, but any fault indication rises. The cable is damaged but there are no signs of that or when the damage is not visible.

**Incipient:** It is one step ahead over the dormant stage. Regarding that, a fault indication can rise for a short time, and then become again in a normal state. Faults can appear as transients or voltage disturbances, but it is easy to go unnoticed. Now, changes in line structure are more noticeable than in the first stage.

**Intermittent:** The fault can be noticed by the rupture of fuses. There are transients or harmonics, which rise in a specific time interval and then the line can operate again in a normal state. A normal state means no fuses blowing but the fault still exists due to the actual differences of the line with the original one, and the probabilities to rise again are more than in previous stages.

**Permanent:** In this stage there is no option to regress to a previous state. Fault, by becoming a short circuit or an open circuit is causing an interruption of the service. It is always an unwanted state, but even today is the unique stage that it is taken into account for repairing a line. Previous fault states are solved replacing blown fuses and leaving lines working again while its state is not permanent. This interpretation has the risk of an increase of the costs associated with many repetitions of the situation. In permanent fault stage the defect can be seen and determine as either short or open circuit faults.

It is important to know about these fault stages when an online monitoring method is being proposed, to take advance of network's knowledge and avoid situations where an outage cannot be avoided and for sure losses will be affecting quality of service. For these reasons, the three first stages are the most interesting, and specifically the dormant and the incipient, where the fault is starting its rising process but there were not impact yet on the electricity distribution system availability.

Even if an online monitoring of the faults is implemented in any area where the ratio of customers is not enough to consider outages costs, it is important to keep a certain knowledge of the network status. This knowledge can help on internal decision making processes in companies. For example, about which parts of the distribution network can compromise the efficiency in the future or which of them may have priority to be replaced [7].

In general ADSL transmission line faults are usually classified as permanent, transient or intermittent fault. A system suffering a hard or permanent fault will exhibit a continuous defect from its specified performance specifications. Intermittent faults can be defined as a temporary or easy malfunction of a device. These type of malfunctions last for a specified period of time, where the device will gradually recover to its normal functionality. Intermittent faults are frequent and occur at periodic and often irregular intervals, separated by a fault. We can define the root cause of an intermittent or soft fault as the measurable symptom of the degradation of some physical aspect of the system. As this degradation increases, the rate and severity of the intermittent symptoms will also increase in vulnerability until gradually the degradation has resulted in the intermittent fault becoming a permanent system fault. Transient faults, however, do not necessarily repeat themselves, single event interaction will cause transient faults. The basic difference is that transient faults are not necessarily considered as symptoms of degradation [7].

### 2.4.8 Asymmetric Digital Subscriber Line (ADSL) Over $T_X$ Line Insulation

#### 2.4.8.1 *WHAT IS Good insulation means*

Every electric wire in any system whether it's in a motor, generator, cable, switch, transformer, etc. is carefully covered and protected with some form of electrical sheath insulation. The internal conductor wire itself is usually copper or aluminum substances, which is identified to be a good conductor of the electric current that energize any kind of equipment. The insulation must be opposite or reverse from a conductor, it should resist and tolerate current and keep the current in its path along the conductor. To clearly understand insulation testing we really do not need to go into the mathematics of electricity, but one simple commonly understood intelligence tells us that the more voltage we have, the more current there will be [8]. Also, the lower the resistance of the wire, the more current for the same voltage. This is Ohm's law, which can be expressed this way in below equation [5]:

$E = I \times R$ Where E → voltages in volts I → current in Amperes R → resistance in ohms

However, insulation is not perfect that has infinite or unlimited resistance so some electricity does flow along the insulation to ground. Such a current may only be a huge number of an ampere but it is the basis of insulation testing device. Note also that from physics a higher voltage tends to cause more current flow through the insulation. This small amount of current would not harm good insulation but would be a problem if the insulation has faded. Now, to finalize and conclude what is good insulation mean ? good means a relatively high resistance to current. Used to describe an insulation material, good would also mean "the ability to keep a high resistance." So, a suitable way of measuring resistance can tell us how good the insulation is. Also, if we take measurements at periodic phases, we can check reasons toward its deterioration [6]. The total current flowing in the insulating material is the summation of three components:

- **Capacitance:** The capacitance charging current necessary to charge the capacitance of the insulation being tested cable. This is a transient current which starts relatively high and falls exponentially towards a value close to zero once the circuit being tested is charged electrically. After a few seconds or tenths of seconds, this current becomes negligible compared with the current to be measured.

- **Absorption:** The absorption current, corresponding to the additional energy necessary for the molecules of the insulating material to reorient themselves under the effect of the electrical field applied.

This current decline much more slowly than the capacitance charging current, sometimes requiring several minutes to reach a value close to zero but cannot be zero.

- **Leakage current:** The leakage current or conduction current. This current characterizes and categorize the quality of the insulation and its stability over time.

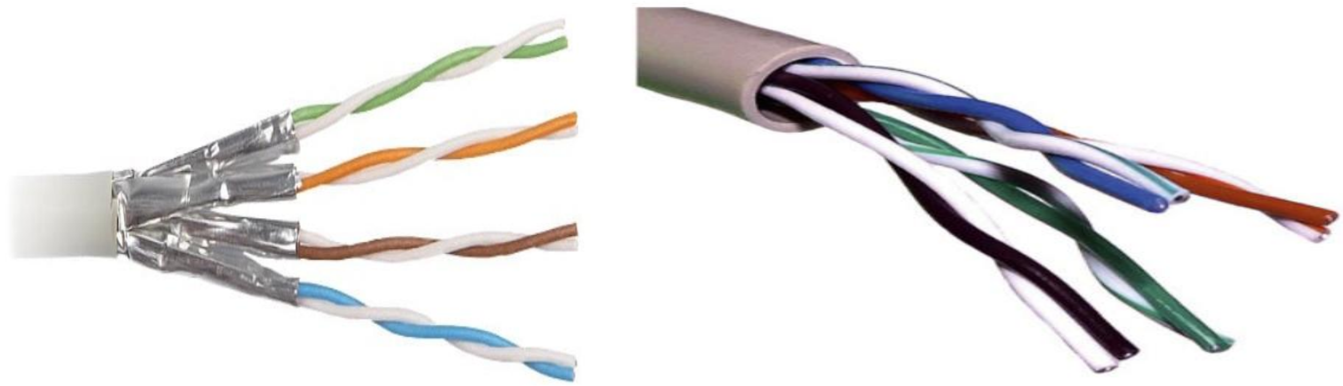


Figure 2- 4: Shielded and Unshielded Twisted-pair Cable [5]

### *2.4.8.2 What Makes Insulation Go Bad*

If we have a new electrical system plant or wired access network and equipment, the electrical insulation should be in top cut shape. Furthermore, manufacturers of wires, cables, motors, and so on have consistently improved their insulations resistance for services in industry. However, insulation is subject and vulnerable to many effects which can cause it to fail mechanical damage, vibration, excessive heat or cold, dirt, oil, moisture from processes, or the humidity on a muggy day. In various degrees, these rivals of insulation are at work as time goes on combined with the electrical system tension that could exist. As pin holes or cracks develop, moisture and external matter penetrate the surfaces of the insulation, providing a low resistance path for leakage current. Once started, the different rivals tend to support each other, permitting excessive current through the insulation. Sometimes the drop in insulation resistance is sudden, as when equipment is submerged. Usually, it drops eventually, giving adequate warning, if checked phase by phase. Such checks allow intentional overhauling before service failure [7].


Fig 2-5: ADSL insulation Detector tools [18].

## 2.4.8.3 How Insulation Resistance is Measured

Previously we have seen that good insulation has high resistance and poor insulation has relatively low resistance. The actual resistance values can be higher or lower, depending up on environmental factors and temperature which may consists moisture in the insulation sheath. With a slight common intelligence, however, we can find a good condition of the insulation condition from values that are only relative [8].

The Megger or the classical insulation tester is a small, portable device that can provide us a direct reading of insulation resistance in ohms or megohms. For better insulation, the resistance usually reads in high ohms' interval. The tester is basically a high range resistance calibration or ohmmeter with a built in direct-current generator. This detection method instrument is built with special structure with both current and voltage coils, enabling actual ohms to be read directly, independent of the actual voltage applied. This method is nondestructive and it does not cause drop of the insulation [8,15].

## 2.5 How ADSL Insulation works

ADSL is a type of DSL technology built with passband system, which means it carries its information in one or more channels beyond the baseband section of the frequency spectrum. It releases the 4 kHz baseband region for use by ordinary voice transmission. In order to transmit data at high rates over a relatively lossy medium, the hardware must implement comparable techniques to those employed by standard device. It sends symbol instead of individual by a process called Quadrature Amplitude Modulation(QAM). ADSL has two basic rival standards for implementing this [9].

The recognized regular, Discrete Multi-Tone (DMT), splits the spectrum into 256 4-kHz channels called bins. Some of these channels are used directional and want echo cancellation to prevent distortion or corruption, and the remain of the channels are used for downstream or downlink data only. The baseband voice channel is well separated from these and can be traced by use of a simple splitter device. The impact is similar to a standard voice line and a batch of standard modems operating in parallel to deliver the high bandwidth service, but over a single twisted pair cable [10]. Since many losses of the twisted pair cable access are frequency sensitive, the hardware can optimize transfer rates by monitoring the performance of each individual channel. If the quality deteriorates, then the bit rate can be minimized on that channel, and reassigned to another channel with a better signal to noise characteristic. Bandwidth within individual channels can be optimally used with modulation techniques similar to those employed by traditional modems.

We have seen that Insulation resistance measurement is based on Ohm's Law. By triggering a very known threshold DC voltage which is less than the voltage for dielectric testing and then measuring the current flowing across the tested system, it is very easy to determine or identify the value of the resistance in the tested channel. In principle, the measured value of the resistance has to be high but not infinite it could be result in KW, MW, GW or TW in some cases. This resistance characterization indicates the quality of the insulation between conductor and insulated material11].

The testing is carried out using a multipurpose meter such as the Megger or insulation tester device, which incorporate insulation resistance ranges. The test instrument is located between the core conductor under test and the ground at the same end of the tested cable. Then the insulation testing device tell us fault type either open or short circuit faults [9,13].

If the copper pair is faultless, all insulation values are nearly 10-MΩ (Mega ohms) or beyond. If one or several values get below 500-kΩ, that should notify a physical problem or damage related to possible oxidation, bad functioning splitter on the line, short-circuit in the customer's inside installation etc. Also, value nothing is that the only convenient test revealing whether it is internal or external wiring that is causing the loss in insulation can be done at the introduction with no internal cabling connected to the pair [16].

3

## CHAPTER THREE: TIME DOMAIN REFLECTOMETRY (TDR)/pulse echo

Reflectometry is echo based with a high frequency process and it measures one cable at a time or the cable under investigation and test is itself and of locating an image of its state through finding and measuring from only one end. Also, reflectometry injects a probe signal or trigger a source signal at one or other end of the cable under test. This signal propagates along the cable and each impedance discontinuity encountered fault returns a part of its energy or power towards the injection port and source. The analysis of the received signal provides information on the presence, the localization, and the type of these discontinuities. This information is very crucial and valuable for maintenance operators.

TDR is the easiest and simplest to understand and to operate it, injects or trigger periodical probe or incident signal and the measured signal is basically made of multiple copies and replica of this signal delayed in time. For each copy, the delay is the trip time necessary to reach the discontinuity from the injection point. So, knowing or evaluating the propagation velocity enables to locate the discontinuity or defect. The present invention relates to a method for diagnosing faults in transmission lines of a communication or telephone cable system and identifying abnormalities on a suitable display for technical maintenance personnel since it measures averaging [7].

Accordingly, TDRs are used for testing cable or wired systems and other forms of feeder where they are able to detect, locate and pinpoint issues. As a result, the technique is widely used in any area where there may be long or in accessible lengths of cable that may need to be tested, or they may have faults. Time domain reflectometry can also be used on different printed circuit boards design to locate issues that can arise there as well [8]. Therefore, Time Domain Reflectometry is a measurement approach to determine the electrical wire or cable characteristics by injecting certain waveforms usually impulse signals and observing reflected waveforms. It compares the reflections from the unknown line environment to those generated by standard or given impedance.

| **Fault Detection Technique** | **Strength** | **Weakness** |
|---|---|---|
| Visual inspection | Provide location information | Highly depends on the operator, requires full access to the cable. |
| X-rays | Can detect any kind of defect, provides location information | Requires substantial systems, Expensive & unaffordable. |
| Ultrasound guided wave | Detect insulator defects | Needs complete access to the cable, not suited for branched wires or access limitation. |
| Infrared thermal imaging | Provide location information | Requires complex imaging system, not suited for every kind of fault(may create hot spot) |
| Continuity measurement | Provides quick continuity information | Requires two access points to the cable, does not give location information accurately. |
| High Pot | Can detect insulator defects | will damage the cable under test, requires heavy systems. |
| Reflectometry/pulse echo | Only needs one access point, provides location information, suited for complex topology networks, can be embedded. | Unable to locate accurate location of faults, high power consumption for detection, impedance sensitivity and lacks accuracy in far end. |

Table3-1: A comparison of several fault detection techniques [8]

Similarly, in addition to fault detection and classification, is able to locate the fault, which is useful in a large electrical system and is to absorb a cable as a transmission line and look at its characteristics in this manner. Although it is likely to use instruments such as network optimizer and analyzers and the like to check the reliability of cables this way, this test device is very expensive and not easy to use.

A much advanced approach for many applications is to use classical Time Domain Reflectometry techniques and a specific test device method. This considerably simplifies the operation as well as reducing the cost of the test instrument [9]. Also, many reflectometers techniques are specifically made for portable operation, enabling them to be used far more easily or simply in the scenarios where they are required, i.e. for telecommunications cables that may be deployed under roads, paths, etc.

The TDR methods are used in a big range of scenarios, particularly in the pre location of faults, because it is a better approach to the fault characterization when the scenario has low voltage and low impedance. They are linked to the pulse echo based analysis, where an impulse is introduced in the network, traveling along the cable and the effect of the fault is seen in the reflected wave arriving back to the TDR device.

When the width of the pulse injected in the cable is low, a narrow pulse, then the accuracy could be moderately acceptable, but the attenuation will be high. So, the analysis can only be suitable for short distances. If it is a broad long duration pulse, then the results in longer cables can be seen but the accuracy could not be enough.

There is also a combination of classic TDR with adaptive filtering, trying to avoid requirements of operator's skills for data interpretation and analysis. An algorithm is explained following this mixture, with an intelligent processing of the reflected signal obtained through the technique to find the fault. This is a very interesting point of view because the intelligent processing of the current line state is taking into account the original state through a stored characterization of the cable. Thus, it can compare both states and process how are the error source [16].

In general, this classic fault detection technique is an electronic instrument to diagnose faults in electrical conductors. It is used to test wiring in aircraft and can also be used in Printed Circuit Board (PCB). Transmit a short duration pulse into the circuit which is reflected if there is any damage within the connection or wiring [16]. The reflected signal is generated due to an impedance mismatch; if no change in impedance is encountered then the injected signal will be absorbed in far end.

## 3.1 Time Domain Reflectometry Measurement Principles and Applications

### *3.1.1 Performances of Reflectometry(TDR)*

The most fascinating performances concern of reflectometry is detection and location accuracy. Once a defect is detected and identified, in order to troubleshoot it a maintenance team must get access to the wires by removing different panels setup, which are situated by several screws. This can be quite a time taking activity if the operator has to remove several panels before finding the one that conceals the defect. Then, an accurate and precise location information is needed to focus directly on the good panel [12]. This emphasizes the fact that the reflectometry based troubleshooting tool must be linked to or used in conjunction with a Computer Aided Design (CAD) model of the join inside the system, as the wires may follow a complicated path.

Most classical TDR methods described above can trace a location accuracy of a few percent of the entire length of the wire under test up to a few measured meters long. Long cables suffer from attenuation and dispersion which greatly reduce or affect the location accuracy. Indeed, the peaks of the reflectometry must be very sharp if one wants to provide a precise estimation of their location. But sharp spark means the use of high frequency or high data rate signals for TDR classic based methods. So, the accurate detection of the edge of the peaks requires powerful data processing or very quick and frequent sampling, which increases the complexity and dynamics and the cost of the detection system. Alternative methods have been proposed, such as the use of oversampling techniques. However, another limitation to accuracy is due to the precision of the knowledge of the propagation speed $V_p$ of the signal. the systems only measure a round trip time $\tau$, then the distance to the defect is obtained.

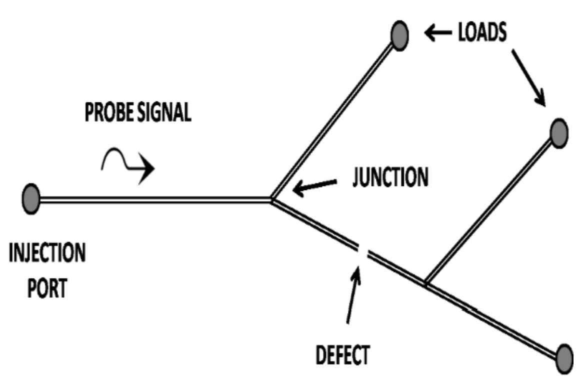



**Figure 3-1:** Network under test [12]

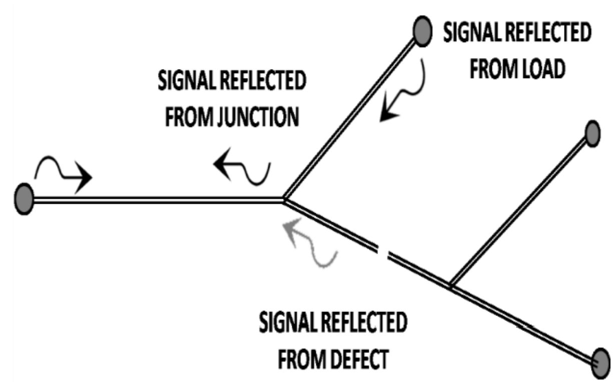



**Figure 3-2:** Principles of reflectometry [12]

Uncertainty on the value of propagation speed ($V_p$) obviously reduce the accuracy on the value of the distance to the defect. But we have seen previously that the propagation speed depends on the frequency. Then, as the probe signal's bandwidth may be extremely large, it is not possible to precisely define or determine the propagation speed for the whole. Last limitation of classic TDR methods is the so called blind zone. If the TDR system is not matched to the inherent or intrinsic impedance of the cable, a part of the energy of the injected signal is directly reflected back, without even going inside the cable. This creates an additional high amplitude peak at the beginning of the reflection point which may hide a defect close to the injection point [12].

Time domain reflectometry fault detection method is so far partially accurate and automatable method for determination of defect media water content and electrical conductivity. Moisturized content is inferred from the dielectric permittivity of the medium, whereas electrical conductivity is conditional from the signal attenuation and signal reduction. Empirical and dielectric mixing models are used to relate moisture content to measured dielectric permittivity. Clay and organic matter binds substantial amounts of moisture, such that measured bulk dielectric constant is reduced and the relationship with total moisture content requires individual calibration. A variety of TDR probe configurations provide users with site and media specific options. Advances in TDR technology and in other dielectric methods offer the promise not only for less expensive and more accurate tools for electrical determination of water and solute contents, but also a host of other properties such as specific surface area, and retention properties of absorbent media [13].

The time domain reflectometer operates by sending a short pulse along the test line in question. With the far end terminated in the required impedance, i.e. that of the line, if there are no problems with the line, then all the energy in the pulse will travel along the line at the propagation velocity and be dissipated in the load and no reflection will be observed.

In general TDR have the following characteristics:

- Higher Power in the signal, which can damage both network elements card & CPE if not disconnected
- Interference with other signals and Susceptible to noise
- Narrow time or short pulse and high impedance sensitivity

The working of a TDR highly depends on the impedance of the transmission line. Impedance is described as the resistance offered by an electronic circuit to an electrical signal. Impedance can be described in two approaches: (1) circuit impedance (Z) called load; and (2) characteristic impedance ($Z_0$) called transmission line impedance. Circuit impedance is the result of the interaction between the resistive, capacitive, and inductive portions of the electronic circuit. Both the capacitive and inductive portions of circuit impedance depend on the frequency of the signal applied to the circuit. Electronic circuit impedance (Z) can be expressed as:

$$|z| = \sqrt{R^2 + (2\pi f l - 0.5\pi c)^2} \text{-----------------(1)}$$

Where, *R* =*DC*-Resistance, *C* = Capacitance, *L*= Inductance and *f* = Signal Frequency

Characteristic impedance is defined as the ratio of voltage to current of a wave moving down a transmission line. The resistance of a transmission line is typically small enough to be neglected. For a lossless line $z_o$ can be expressed by:

$$z_o = \sqrt{\frac{L}{C}} \text{------------}(2)$$

When mismatching of impedance occurs, results in electromagnetic discontinuity. The reflectometry signal's velocity of propagation $v$ is related to:

$$\frac{Delay}{2} * v = Length$$

The relative dielectric permittivity $\varepsilon_r$ of the medium, which is assumed to be lossless or with negligible conductivity, and the relative magnetic permeability $\mu_r$, by the following equation:

$$v = \frac{C}{\sqrt{\varepsilon_r \mu_r}} \text{-------}(3)$$

Where $c = 3*10^8 ms^{-1}$, which is the velocity of light in vacuum, while the relative magnetic permeability is unity in most materials, such as liquids. Velocity of propagation in terms of velocity of light is given as:

$$v = \frac{1}{\sqrt{\varepsilon_r}} \text{-------------}(4)$$

When an impedance mismatch occurs, a part of the incident pulse is reflected back toward the step generator. The ratio between the reflected signal amplitude and incident pulse amplitude gives the reflection coefficient $\rho$.

$$\rho = (\frac{V_{reflected}}{V_{incident}}) = \frac{Z_L - Z_o}{Z_L + Z_o} --------(5)$$

The reflectivity change at the defect or impedance mismatch between material interfaces can be related to the reflection coefficient through the equation:

$$\varepsilon_r = (\frac{1-\rho}{1+\rho})^2 --------(6)$$

Also, in the case of a TDR fault detection probe traversing from the source end to the far end of a cable consists of conducting material filled with a similar material or different material area or length D, the dielectric constant of the cable tested can be evaluated as:

$$\varepsilon_r = (\frac{D_a}{D})^2 ---------(7)$$

Where *D* is the distance of the signal from the first point of discontinuity to the new mismatch point this is typically a short or open circuit terminating the probe, and $D_a$ is the corresponding apparent distance in air, measured by the TDR method set-up. the second mismatch occurs can be measured, as:

$$D = \frac{D_a}{\sqrt{\varepsilon_r}} --------(8)$$

The spatial resolution is the ability of the TDR to distinguish between closely spaced anomalies. It depends on the rise time of the TDR. Two discontinuities are indistinguishable if separated by less than the rise time. Hence, faster the rise time of the TDR, sharper its spatial resolution.

The spatial resolution $d_{\min}$ is related to rise time $t_{rise}$ of the TDR as:

$$d_{\min} = \frac{c * t_{rise}}{4\sqrt{\varepsilon_r}} ------------(9)$$

*Where C is velocity of light in vacuum and* $\varepsilon_r$ *is relative dielectric permittivity of the medium.*

The following examples illustrate the usage of the signal flow graph. the TDR tester sends out a voltage signal down the transmission line. The reflection created can be neglected if the characteristic of tester's impedance matches that of the transmission line $Z_0=Z_1$. The magnitude of the reflected signal can be calculated as:

$$\tau_0 = \rho = \frac{z_1 - z_o}{z_1 + z_o} ---------(10)$$

With the basic analysis signal flow graph of a single section transmission line shown in Fig 3-3, we can easily enlarge the model to simulate multiple sections. Let us assume the impedance of the tester matches the first section of the transmission line. We can remove the initial reflection $\Gamma_0$ from the graph. The resulting signal flow graph is shown in Fig 3-3 below, where $L_1$ block represents the first section while $L_2$ represents the second section. Comparing the blocks $L_1$ and $L_2$ we noticed that they are functionally identical.

By representing them as big blocks with two pairs of input outputs, we can highly simplify the signal flow diagram as shown in Fig 3-4. Similarly, we can further cascade the configuration to N sections as shown in Fig 3-3. The ability of cascading block diagrams as connecting sections of transmission lines makes this method easy to use and more flexible. The properties of the transmission lines can be built in each block and the users only need to connect them together.

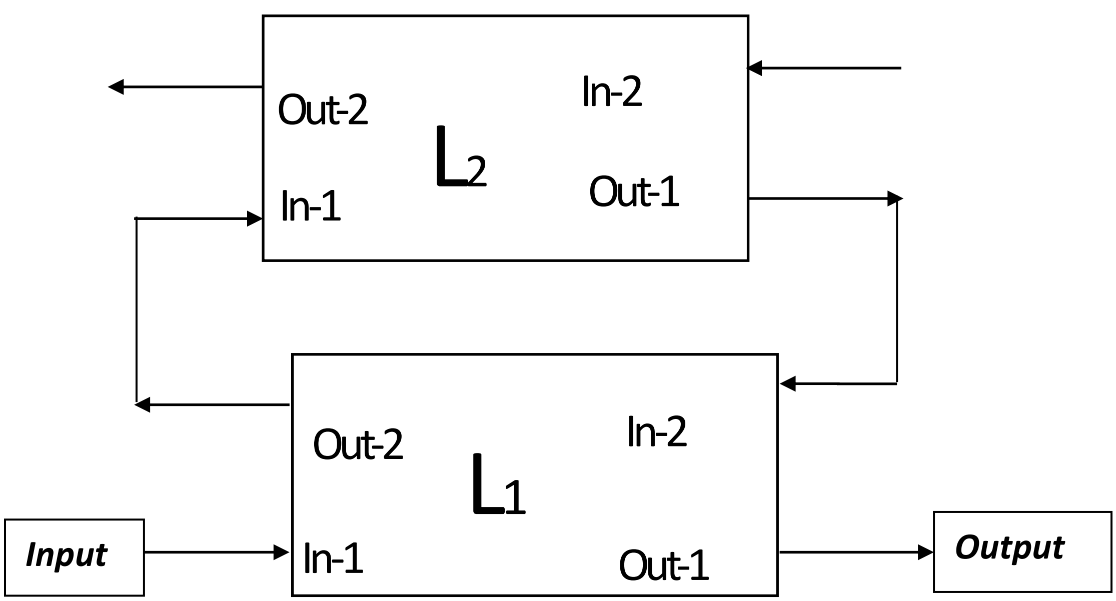



Figure:3-3: Simplified block diagram for a two-section configuration [13]

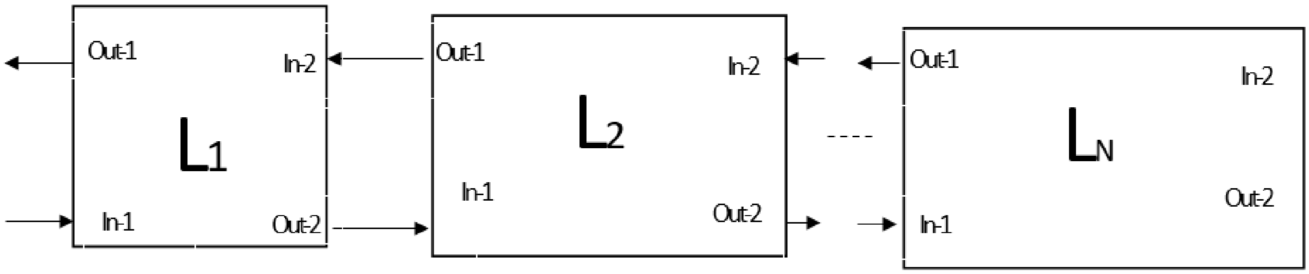



Figure 3.4: N-section block diagram

In the telecommunications industry TDR is used to identify locations of discontinuities and permanent faults in cables, hence the term cable tester is a common name for general purpose detection instruments. The signal propagation velocity $V_p$ a function of the cable dielectric constant, along with a typical reflection at a point of defects in a cable, allows the operator to determine locations of line breaks or other damage to cables using travel time analysis. Using similar principles, a waveguide or probe of known length $L$ may be embedded in soil and the travel time for a TDR generated electromagnetic slope to traverse the probe length may be determined. From the travel time analysis, the soil's bulk dielectric constant is computed from which the volumetric moisture content is inferred [13].

The bulk dielectric constant $\varepsilon_b$ of soil surrounding the probe is a function of the propagation velocity: ($v = \frac{2L}{t}$) according to:

$$\varepsilon_b = (\frac{c}{v})^2 = (\frac{ct}{2L})^2 ------12$$

Where $c$ is the speed of light (velocity of electromagnetic waves) in vacuum $(3\times10^8)ms^{-1}$, and $t$ is the travel time for the pulse to traverse the length of the embedded waveguide (down and back: $2L$). The travel time is evaluated based on the 'apparent' or electromagnetic length of the probe, which is characterized on the TDR output screen by diagnostic changes in the waveform: $x_1$ marks the entry of the signal to the probe, and $x_2$ marks the reflection at the end of the probe. The between locations of the two reflection points $x_1$and$x_2$, and the bulk dielectric constant is:

$$\varepsilon_b = \left(\frac{x_2 - x_1}{v_p L}\right)^2 \quad - - - - - 13$$

where $V_p$ is a user selected relative propagation velocity, often set at $V_p$=0.6. For most practical applications it suffices to consider the definition of the dielectric constant in equation above, which simply states that the dielectric constant of a porous medium is the ratio squared of the propagation velocity in vacuum relative to that in the medium [13].

In so far analysis TDR is impedance sensitive and narrow pulse which lacks accuracy on locating of faults in real scenario, now a day's most of wired telecom service providers are using this obsolete technique which are very prone to error. One of the technique to counter this is to use the so called distributed reflectometry. The recent detection technique which has good efficiency, accuracy in fault detection relative to TDR and that has been verified in aircraft communication and on some electronic and electricity transmission line is the so-called spread spectrum technique will be analyzed in the next chapters.

4

# CHAPTER FOUR: SSTRD FOR ADSL FAULT DETECTION

## 4.1 Spread Spectrum

Spread spectrum is a technology for a means of transmission in which the signal occupies a bandwidth in excess of the minimum necessary to transmit the information; the band spread is accomplished by means of a code which is independent of the data, and a synchronized reception with the code at the receiver is used for despreading and successive data recovery. The transmitted signal is a greater bandwidth than needed for the data being transmitted. Spread spectrum techniques were initially used for military applications such as radar and secure communications. This is due to the number of built-in advantages spread spectrum communication techniques have over conventional systems. Some distinct benefits include anti-jamming, anti-interference, low probability of intercept, and multiple user random access communications with selective addressing capability [14,19].

In general Spread spectrum (SS) concept is a means of transmission in which:

- The transmitted signal occupies a huge bandwidth greater than the minimum necessary to send the information.
- Spreading is accomplished by means of a spreading signal called a code signal, which is in dependent of the original data or information.
- At the receiver end, de-spreading is done by correlating the received spreaded signal with a matched replica of the spreading signal.

Essentially, it is important to understand that spectrum is a general term used to include the spatial and time based properties of any medium, including fiber optic cable, coaxial cable, and ambient air. From the view of a strict constructionist, spectrum is a type of division based on frequency or wavelength [19].

### 4.1.1 Application and Operation of Spread Spectrum Technology

Advantages:

- Has the ability to eliminate or alleviate the effect of multipath interference
- Ability to share the same frequency band with other users and Low energy in the signal time
- Minimal or “NO” interference, Noise immunity and Resists intentional and non-intentional interference
- Broad Features allows it to be used in live aircraft wires and live environments
- Easy interpretation of faulty picture and high accuracy
- Offers the ability to be used in high noise and live environments.
- It is also good at locating faults with a higher precision due to higher operating resolution.

Disadvantages:

- Bandwidth inefficient
- Implementation is somehow more complex due to different algorithms.

### 4.1.2 Spread Spectrum Time Domain Reflectometry

There is a modification in the classical TDR method using the spread spectrum technique to detect changes in impedance even in high noise environments, such as power lines. With this method, the problems associated in TDR with the distance and the resolution are tried to be solved. In such environment the test can be performed in a continuous mode, allowing the detection of intermittent failures. The main disadvantage is the dependence with the level of Signal-to-Noise Ratio received, which determines the correlation results [15].

There are a number of different reflectometry techniques, namely time and frequency based called TDR and FDR or JFTDR. SSTDR is another concept of reflectometry technique used to identify the continuity faults in the electronic circuits [16]. The technique has advantage on other TDR because it offers the ability to be used in high noise and live environments. It is also good at locating faults with a higher precision due to higher operating resolution. The working principle of SSTDR is to modulate the signal with Pseudo random code and cross correlate the source signal with the reflected signal to check the continuity faults in the circuits.

### 4.1.3 Correlation Pulse Echo Techniques: Pseudo-Random Binary Sequences (PRBS)

As a new alternative to the TDR techniques, a correlation pulse echo methodology by applying pseudo-random binary sequences has been established. The main purpose of using this technique is its tendency to clearly identify the fault position through a well-defined algorithm, identifying the reflected pulse, which can prevail with regard to the noise present in the communications channel. This reflection or algorithm is based on the high correlation levels that can be reached between a PRBS injected in the cable and the reflected sequence in a mismatch that occurs due to a defects.

One of the problems suffered by narrow pulses when they are injected into a cable with the traditional TDR methods is the attenuation in long distances. To partially solve this, wider pulses can be used, but by doing this, the accuracy of the location process decreases. With this new method the operation distance can be improved [16] from previous history of this particular algorithm.

A spread spectrum signal can be injected now into an offline or live environment cable and when the signal will be analyzed when the reflected signal is mismatched with sent signal, at the same time the received signal is correlated with the sent signal to analyze the differences. The technique has been tested in noisy environments, such as a simulated aircraft in flight successfully but considering lossless cables. Then, they can be compared to measure the delay between them. The obtained delay is the value, which provides the estimation of the distance where the fault has to be located, using line's velocity of propagation [18].

Although, SSTDR has a number of features that is to measure entire length of the cable & to identify faults in a good detection ability and locating defect points, usually in electrical and aircraft wires, by analyzing reflection or counter spread spectrum signals. This type of time domain reflectometry can be used in various high-noise and live environments [17]. SSTDR has been commercially proposed to detect wiring faults and has low test signal levels and high noise immunity, which make it a viable solution to detect live wires fault in energized systems [18].

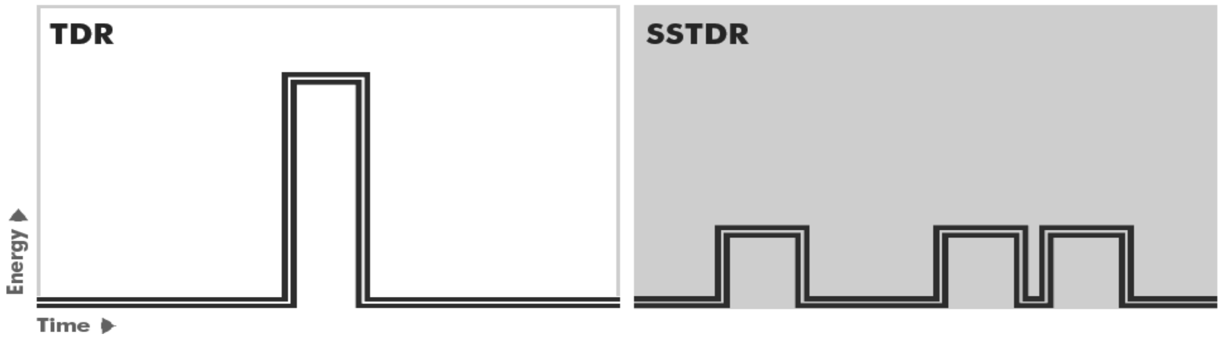



Figure 4-1: TDR vs SSTDR signal reflection [18].

Basically, SSTDR uses the same physics as the classical TDR and incorporates the use of Pseudo-Random Noise and Spread Spectrum frequencies. Pseudorandom Noise signals are specific digital signals that are not interfered by and do not interfere with other signals on the line hence it has its own code for identification purpose. However, SSTDR used different algorithms and functions for the reflection against the transmitted or injected signal to generate some sort of waveform. The spread spectrum algorithms are then applied to automatically identify fault type and provide a location information to the user without the need for interpretation.

A Spread Spectrum of frequencies can be used to carry out the test for a transmission line. The spread of frequencies provides, Accuracy at shorter distances by using higher frequencies, whilst the low frequencies allow monitoring of longer cables. Usually TDR will have its place and copy for carrying out spot test signal on transmission line cable systems and periodic testing. SSTDR, however, provides an appropriate alternative to this command as its continuous monitoring and detection of live systems enables the user to respond to emerging and critical faults as they happen while eliminating or avoiding the requirement for powering down the system to carry out intrusive tests [19]. In SSTDR reflected signal will notify time shift between two signals and Signals are so small below the allowable noise margin of any signal and it could operate by shifting the signal in time, multiply them, integrate, or add them.

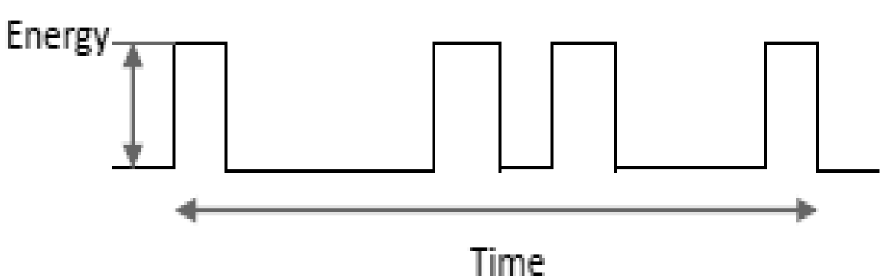



Figure 4-2: SSTDR reflection signal [12].

Spread spectrum signals are detectable through correlation pulse echo techniques (pseudo-random sequence algorithm), even though they may be added with noise. The ability to select out the reflected signal is due to processing gain, which can be expressed as:

$$PG = \frac{T_s}{T_c} = \frac{R_c}{R_s} = \frac{W_{ss}}{2R_s} = \frac{B_t}{B_i} \text{---------------------------------} (14)$$

Where $W_{ss}$ is the bandwidth of the spread-spectrum signal, $T_s$ is the duration of one entire spread spectrum sequence by considering the entire sequence equal to one bit in communication system, $T_c$ is the duration of a PN code chip, $R_c$ is the chip rate in chips per second, and $R_s$ is the symbol rate, $B_t$ is transmitted bandwidth and $B_i$ is information bandwidth, which is the number of full sequences per second [21].

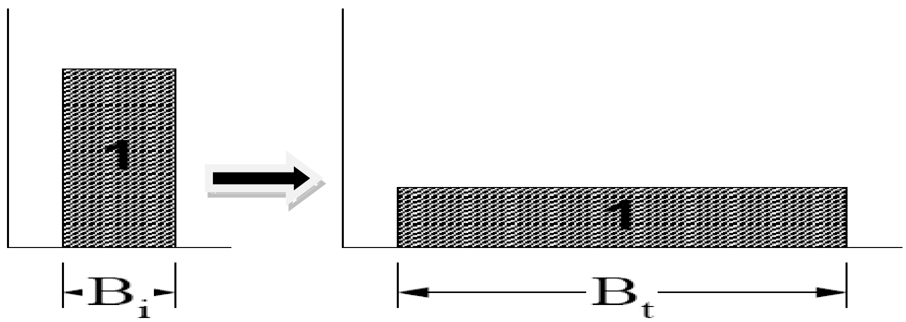



Figure 4-3: TDR vs SSTDR bandwidth signal [21].

In general, the intention of spread spectrum is transmitting the information signal bandwidth in to transmitted bandwidth that can use to measure far end distance. Therefore, SSTDR is a method of fault detection based on spread spectrum technique. In this application, the random sequence generator is modulated by any wave form in the same frequency, generating the test signal $s(t)$ for the detection technique. The correlation between the probe and reflected signals identifies the type of fault and its location. In the beginning, the test system will send a probe signal $s(t)$ onto one end of the cable, which will be reflected by some arbitrary number of impedance discontinuities on the cable. Signal correlation is made with the sent sequence by autocorrelation, ACR and with the reflected sequence from the fault by cross-correlation CCR, obtaining clearly defined reflection result of existing mismatches [22].

## 4.2 Correlation Algorithm

### 4.2.1 Expected Correlator Output with Generalized Noise

Correlation function algorithm can be the core of the fault detection analysis, particularly for the broadband technology transmission cable fault detection system using spread spectrum time domain reflectometry technique, which reflects the dependency of the test signal and reflected signal. When the test signal and the reflected signal are identical in phase, a unique maximum will be output. Using correlation function, the system can identify the time difference between the test signal and the reflected signal, then the cable fault location can be obtained [9]. Since the reference signal is so low, the test signal, because of attenuation, becomes quite weak when it is reflected back again from the fault point.

The challenge is the reflected signal, usually interfered by some noise signals, will suffer serious deformation. Through the correlation algorithm, the system can make the reflected signal, even if submerged in the noise, be identified easier, improving the anti-interference ability of SSTDR. The correlator output can be analyzed in terms of the signal injected onto the cable, various reflections of that signal, and any unwanted signals (noise) received at the correlator input. Let *S[n]* be a recursive linear sequence of period '*K*' consisting of *1s* and *1s* [21,22].

Then let $s(t) = S[n].p(t-n_T)$-----------------------------------------------(15) where

$p(t) = 1,\ 0 \le t \le T_c$ 0, $otherwise$ -------------------------------(16)

so that $s(t)$ is a recursive linear signal (RLS) of period $T_s=KT_c$ consisting of *1s* and *1s*. Here, $T_c$ is the minimum duration of a *1* or *1*, otherwise known as a chip. Note that and $n_T$ is a delay duration of noise signal.

$s(t) = s(t-T_s)$ ----------(17) for any $t$ for recursive linear sequence(RLS) of duration $T_s$.

The test system will send a signal $s(t)$ onto the cable, which will be reflected by some arbitrary number of impedance discontinuities in the cable. The reflected signals will return to the test system after some transmission delay. Along with the reflected signals will be some noise that will depend on the nature of the cable being tested, anomalies in the signal generation, and extraneous noise. Let *x(t)* be the received signal, defined as:

$$x(t) = \sum_k \alpha_k \, s(t - T_k) + n_k \text{------------------------------}(18)$$

where $\alpha_k$ is the amplitude of reflected signal $\alpha_k s(t - T_k)$ relative to $s(t)$, $T_k$ is the time delay before receiving reflection $K$, and $n_k$ is a noise signal of duration $T_n >> T_s$, that is statistically uncorrelated to $s(t)$. The correlator output will be

$$R_{sx(T)} = \int_0^{T_s} s(t) x(t - T)\, dt$$

$$= \int_0^{T_s} s(t) \sum_k \alpha_k \, s(t - T - T_k) dt + \int_0^{T_s} s(t) n(t - T) dt \text{--------------------------------------}(19)$$

As can be seen from equation (15), the correlator output will depend on the reflected signals and the noise, and is, Therefore, determined by both deterministic and nondeterministic signals. The expected value $E(.)$ of the correlation $R_{sx(T)}$ must, therefore, be considered

$$E\{R_{sx(T)}\} = E\left\{\int_0^{T_s} s(t) \sum_k \alpha_k s(t - T - T_k)\, dt + \int_0^{T_s} s(t) n(t - T) dt\right\}$$

$$= \int_0^{T_s} s(t) \sum_k \alpha_k s(t - T - T_k) dt \text{--------------------------------------------------------}(20)$$

In the final step in equation (20), $s(t)$ and $n(t)$ are uncorrelated. The output of the correlator in the absence of noise is the sum of cross correlations of scaled and time-shifted copies of $s(t)$ and the original $s(t)$. The expected output in the presence of noise is the same as the output in the absence of noise, with some additional random noise term that is zero mean [21].

### 4.2.2 Correlator Output in the Presence of White Noise

The cross correlation of noise terms with $s(t)$ can be discussed in terms of the nature of the noise terms. If $n(t)$ is white Gaussian noise, the cross-correlation analysis can be described explicitly [11]. From (equation 19 and 20), the cross correlation $s(t)$ of with $n(t)$ has mean

$$E\{R_{sn}T\} = E\left\{\int_0^{Ts} s(t)n(t-T)dt\right\} = 0 \text{-----------} (21)$$

and variance

$$E\{R_{sn}T^{2}\} = \frac{No}{2} Es \text{----------------------} (22)$$

where $N_0/2$ is the noise power received at the input, and $E_s$ is the energy in the reference signal $s(t)$ over one period. Thus, the effect of noise in the system will be to add variation to the measurements proportional to the energy of the signal $s(t)$, but it will not cause a consistent DC offset. Equations were developed to enable system design by describing the interactions of the SSTDR signal and various types of noise in the correlator output.

Equations were developed to describe the effects of scaling test system parameters including the number of chips in the PN sequence and the PN sequence chip rate used for spread spectrum. It was shown that doubling the PN code length doubles the SNR independent of the noise type, and that doubling the chip rate (and modulation frequency for spread spectrum) in the presence of copper line (ADSL) can increase the SNR for SSTDR techniques. PN codes are the optimal codes to use when performing multiple interacting tests simultaneously. But for this particular research Kasami code generator will be used as sequence generator.

$$r(t) = \alpha_i s(t - t_i)$$

The reflected or reverse signal $r(t)$ will return to the test system after some specific transmission delay. Usually, along with the reflected signal will be some noise signals. Cross-correlate the total signals with the reference signal delayed by *t*, and by changing the delay time $_t$, to make cross-correlator output maximum value. According to the feature of cross correlation, at the point, there is $t = t_i$ is the reflection time corresponding to the cable fault point. If the velocity of the signal is known, multiply it with the time *t*, the fault point can be obtained. Finally, the system can tell us the fundamental difference between the open and short-circuit fault by analyzing the highest peak of cross-correlation.

Let the velocity of the signal is constant in the transmission cable, $v_p$ multiplied with the speed of light. If the propagation delay τ of the reflected signal is found, the fault location length (*L)* can be obtained from the following formula:

$\varphi = {}^{1}/_{2*v_p*c}$ and $l = \varphi * \tau$ Where: $c = 3 * 10^8 \, {}^{m}/_{s^2}$ speed of light & τ is delay, $v_p$ propagation speed and $\tau_i$ = transmission time delay

Ideally test signal depends on the nature of the application. For single cable, we select maximum peak, modulated by sinusoidal signal in the same frequency, as the test signal for SSTDR. The autocorrelation of maximum peak length has obvious high value and has the lowest side lobes, so the reflected signal can be identified easily. Therefore, optimal for detecting the fault of single cable. Maximum length reflection is shortened from the largest linear feedback shift register sequence. From below linear shift register sequence using SSTDR fault detection method a lot of intermittent and discontinuities can be analyzed and used to measure the degree and frequency of the fault along the transmission line.

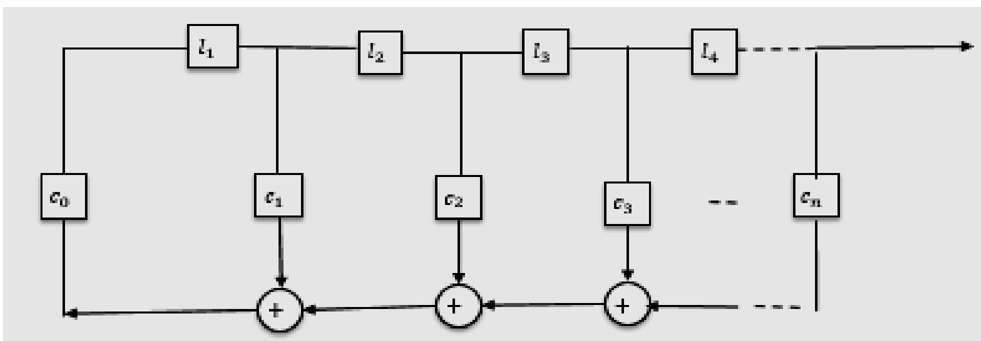



Figure 4-4: N-linear shift register for SSTDR [21]

$$f(x) = c_0 + c_1x + c_2x^2 + c_3x^3 + \ldots + c_nx^n = \sum_i^n c_nx^n$$

where $c_0$ is coefficient of the reflected signal or it can simply tell us the amplitude of the reflected signal and $x^n$ is the order or the degree of the intermittent cycle which will let us to know where the first, second and the next intermittent and fault could exist.

Because of its processing gain, it is reasonable to assume that a spread spectrum test system could operate correctly in a noisy environment with 4kHz to 2208 kHz and 115V AC or digital data on the wires. The test system could be designed such that it would not be damaged by or interfere with any of the signals already on the wires. The system operates on low-defect (3 dB/100 m) shielded twisted pair cable and allows for a SNR of (15-17dB).

Sequence generator codes were identified as the best code to use for testing single wires at a time due to the higher self-induced noise present with other code choices. The work covered in this thesis shows that SSTDR can be effective tools for locating defects on live cables, and this was demonstrated for both controlled and uncontrolled impedance cables carrying frequency of ADSL from 4 kHz to 2208 kHz.

## *4.3 Basics signal propagation of SSTDR Technique*

Impedance discontinuity leads to reflection of travelling signal at impedance disruption $Z_L > Z_i$ a signal portion is reflected back Transmitted signal travels further, get reflected at the event exit $Z_F > Z_L$ and travels to the source at the cable end, the remaining signal is reflected back, Cable properties and fault location easy to determine Reflection coefficient ρ = $V_{reflected}/\ V_{incident}$

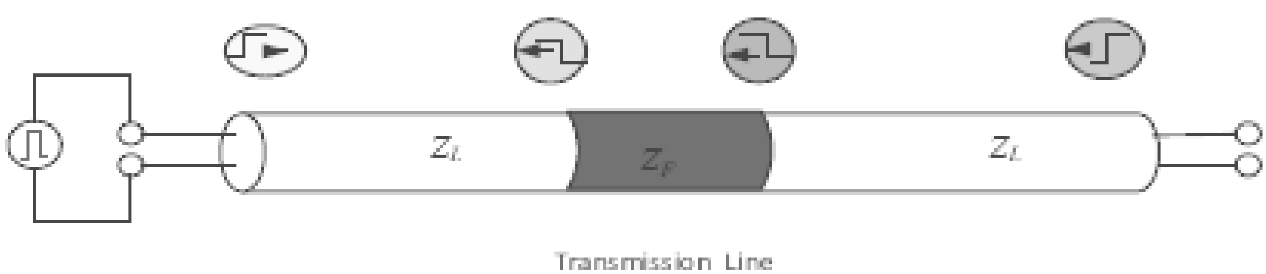



Figure 4-5: reflection of travelling signal at impedance disruption for Transmission

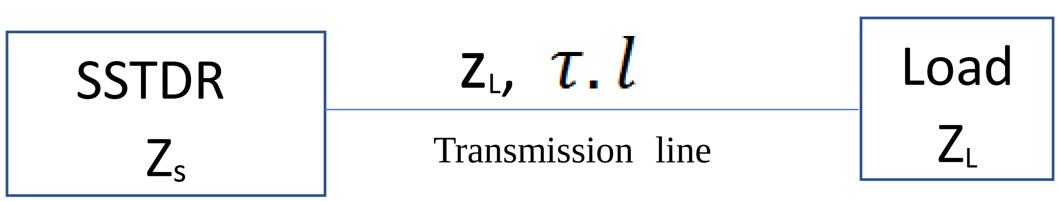



Figure 4-6: fault detection layout and signal at impedance disruption for Transmission line [22]

Various length of cable tested under open, splice and short circuit conditions, Characteristic impedance of the cable easily determined the location of the fault or impedance discontinuity can be determined using propagation delay. Proposed block diagram of SSTDR for ADSL transmission line is:

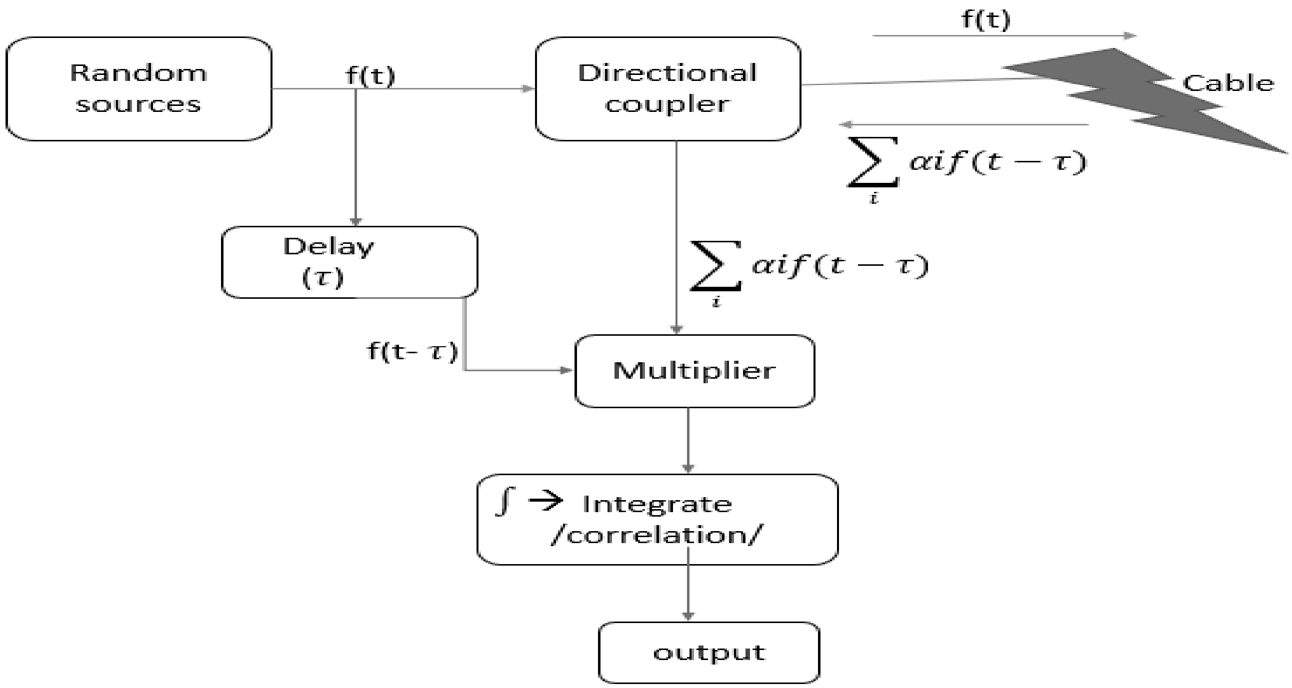



Fig 4-7: Proposed Block Diagram /Model for SSTDR fault detection

- **Random sources:** An arbitrary signal that cannot be defined by an explicit scientific relation. Rather, the value or effect of the signal at a certain time may be expressed only in terms of some describable probability of existence. Accordingly, there is a range of "frequencies" that may be used to characterize the function. In case of this research random sources are a combination of sinusoidal signal modulated by sequence generator. For the SSTDR fault detection technique scenario Kasami sequence generator is modulated with sine wave as probe or source signal for modelling and simulation purpose.

- **Directional couple:** is a device or tool that samples a small amount of Microwave power for measurement purposes. The power measurements include incident power, reflected power, VSWR values, etc. Directional Coupler is a 4-port waveguide junction consisting of a primary main waveguide and a secondary auxiliary waveguide.

- **Multiplier:** In electronics, is a device which takes two signals and yields an output which is their product. This type of circuits can be used to implement related functions such as squares, and square roots. It multiplies the reflection of the coupler with the source/probe in specified time delay.

According to the correlation function theory, the test signal *s*(*t*), whose autocorrelation has a certain periodicity, when more than one cycle, there will be more than one auto-correlation peaks, which may be confused with the cross-correlation of the cable fault point, resulting in misjudgment. So, the correlation must be completed in a cycle time. However, the fault location cannot be achieved if the fault point is too close to the test end, with the superposition the *s*(*t*) autocorrelation and the cross-correlation. The entire fault detection model and manipulation of the investigation could be analyzed by the below mathematical approach.

- Incident signal
  - Sine wave with sequence generator
  - Sinusoidal signal: $s(t) = A \sin 2\pi f \tau_i$
  - Kasami: $k(t) = \sum_i^n M_n$
- Reflected signal

$$f(t) = s(t) \times k(t)$$

- TDR:

$$r(t) = \sum_i^n \alpha_i \, s(t - \tau_i) + n(t)$$

- SSTDR:

Resultant signal after cross-correlation:

$$R_{sr}(t) = \int_0^T r(t) f(t - \tau_i) \, dt$$

Where A is amplitude of the source signal f: frequency in Hz and τ: is time delay of each sample

Where

- S(t)=incident signal
- $\alpha_i$= coefficient of reflection signal
- n(t)=noise→AWGN
- $\tau_i$ =transmission time delay

Distance of fault location can be calculated by:

$\varphi = {}^{1}/_{2 * v_p * c}$ and $l = \varphi * \tau$

- Practically the experiment can be demonstrated by the above experimental setup in the laboratory in order to verify the theoretical analysis with practical visualization. In both scenarios the following parameters are used.
  - A: Amplitude of the incident signal is set to =0.5 mv
  - f =10Hz: frequency of modulated signal

- $\tau_i$: time delay can be calculated from distance and velocity equation
- Pulse width=0.1ms (specified for simulation purpose)

- Frequency mapping or sampling of Simulation **Vs** Real time frequency (Hz**)**
    - 1:10MHz
    - 10:1000MHz:1GHz
- Distance mapping
    - 1:1000m=1km

***NB:*** The above frequency and distance mapping is work only for simulation purpose in this study.

All mathematical manipulation and simulation is based on the above fundamental parameters and quantitative figures. In this research the model and the experiment have been analyzed by the below logical layout Sample generator could be represented by kasami sequence generator for this specific investigation and sinusoidal signal will be used as a sampler and exerted to the model for the consumption of the analysis in SSTDR fault detection.

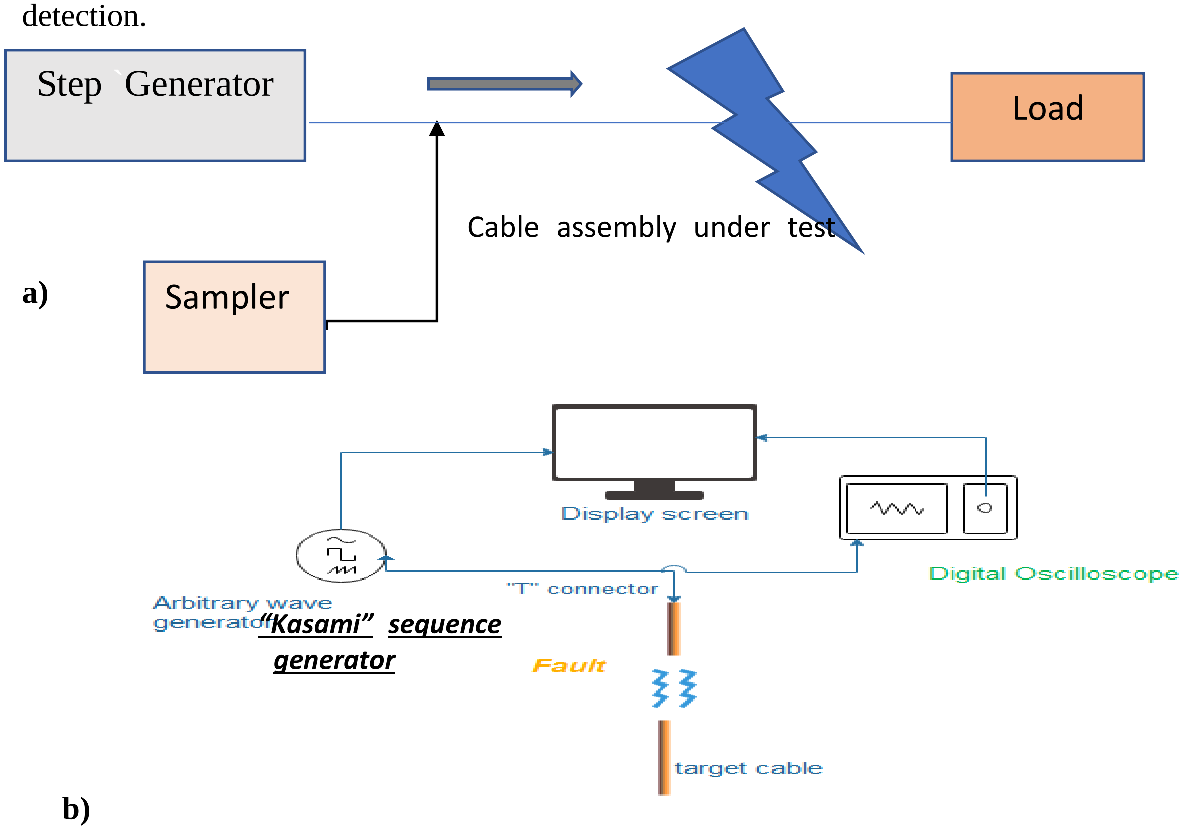



Figure 4-8: logical and physical layout and setup of SSTDR fault detection technique respectively

5

# CHAPTER FIVE: RESULT AND DISCUSSION

In the next section, we will see the simulation result of SSTDR fault detection technique in ADSL transmission line fault for random noise in the channel. Since this thesis is focused to enhance fault detection mechanism using spread spectrum technique in ADSL digital technology. We can confirm that spread spectrum technique has a strong tendency to locate and find where specifically data is lost, and problem is occurred, and it has a strong signal component.

In this Chapter, we are going to demonstrate simulation results on the basis of ideas discussed in previous three Chapters using MATLAB R *2018*a.

| | |
|---|---|
| Source/probe | Sine wave modulated with Kasami sequence generator |
| Sequence generator | Kasami Sequence Generator |
| Transmit power | Equally distributed among all channels with optimal threshold value i.e. 0.5 mv |
| Performance Metric / Verification Parameters | SNR, power & distance are fundamental performance verification parameters |
| Noise | Additive white Gaussian Noise (AWGN) used for Simulink purpose |

Table 5-1 Simulation parameters

Optimization and fault detection requirement and input parameters platform are:

- Laptop Core i*7 3.54*G CPU @ *3*GHz, RAM *8*GB, windows *10*, *64* bit operating system.
- MATLAB R*2018*a.
- Number of coefficient α = 1. . .4 & 1 Km or 1000m ADSL copper cable
- Ethiotelecom network Topology & existing copper cable

## 5.1 Flow Chart

It is essential to visualize the simulation using flow chart since it describes the one's understanding of the whole process easily and it also gives a chance to think where the process can be improved. Flow chart is shown in Figure below.

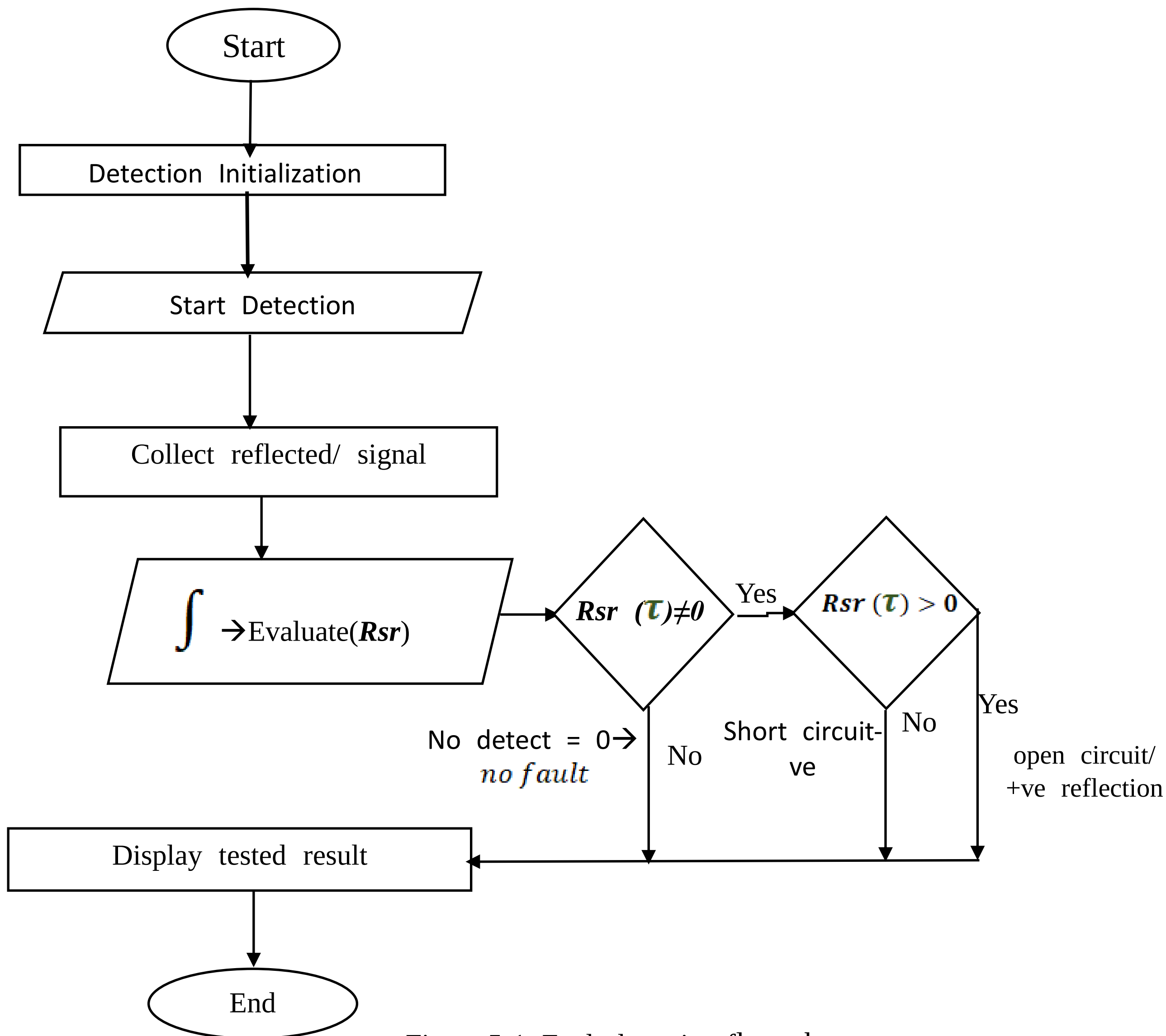



Figure 5-1: Fault detection flow chart

To show the ability of SSTDR to detect and locate short and open-circuit types of fault on ADSL cables, an experimental system was organized as shown in Fig. 5-2 below. The system consists mainly of the transmission line controller that is a computer for experimental, arbitrary waveform generator, digital oscilloscope, and a "T-shape" connector.

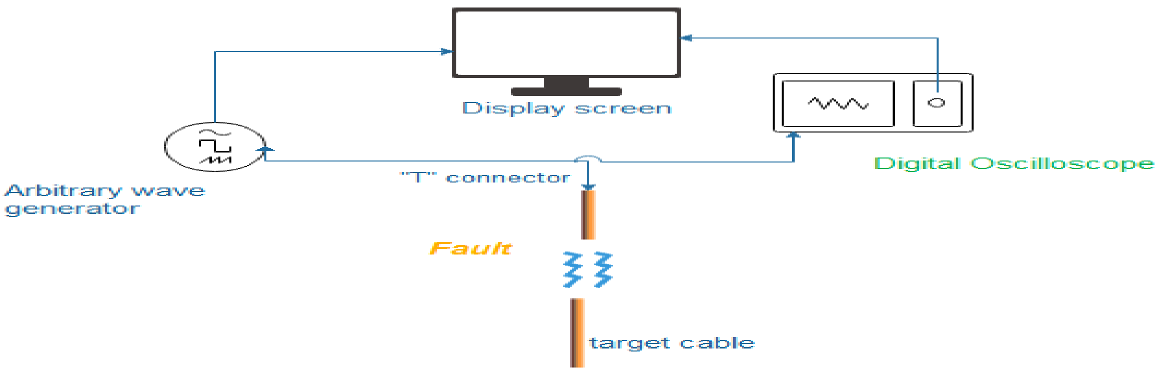



Figure 5-2: Experimental setup for SSTDR & TDR

To automatically control the tools, the arbitrary or random waveform generator (applied to generate some certain frequency of SSTDR test signal) and digital oscilloscope are connected to the transmission line regulator. The test signal is transmitted down or injected to the target cable via one port of the "T-shape" connector. If there is a fault in the cable, because of the change of impedance or impedance mismatch, the test signal will be reflected to the digital oscilloscope device via the other port of "T-shape" connector. The computer controls and synchronizes the random waveform generator and digital oscilloscope, executes the cross-correlation of the incident signal and reflected signals, and finds a propagation time to calculate the exact location of fault. The below model is SSTDR model setup with the following components:

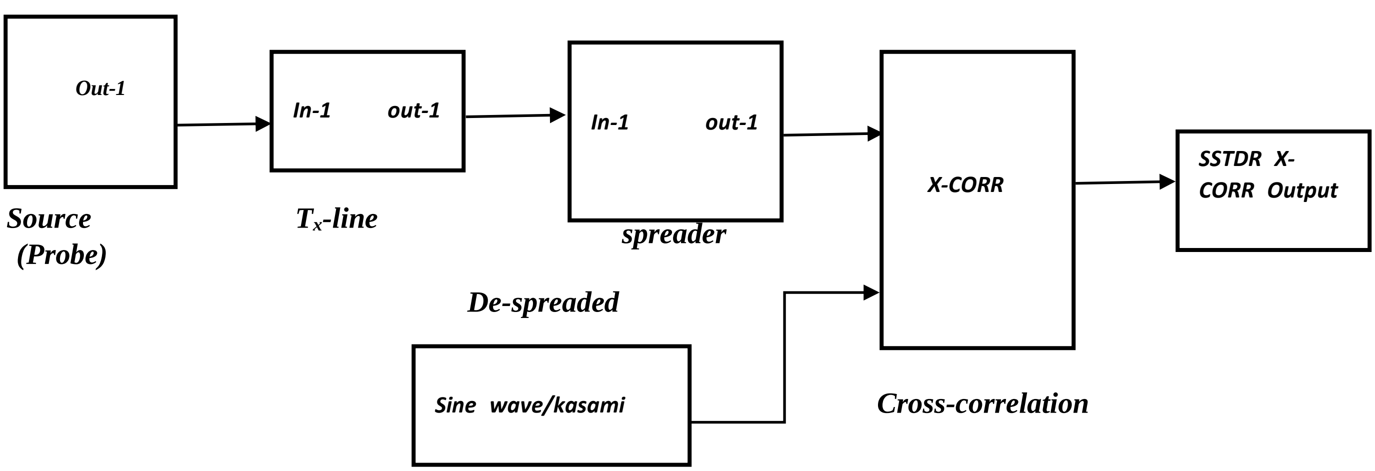


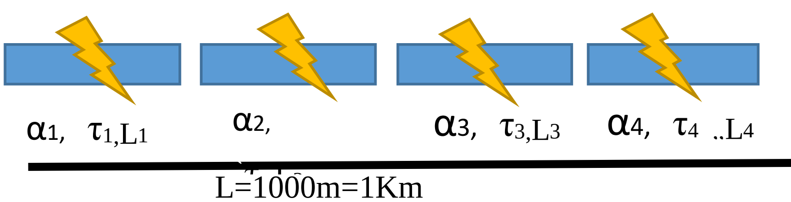

Figure 5-3: Simulation Diagram of SSTDR cable fault detection for ADSL

In order to verify the SSTDR simulation characteristics, the below experiments and simulation were conducted to detect short, open-circuit and distorted faults at different lengths of ADSL transmission line. Also note that the samples for reflected signal achievement of the SSTDR technique is 10 MHz for actual work set-up. Let the incident signal chip rate is $T_c$=1/40 MHz, and the amplitude of the incident signal is set to 0.5mV. The length sequence generator of (Kasami) is N=41. it can be known the range of the cable length which can be tested: 1 m ≤ $L$ ≤ 1000 m. The reflected or spark signal waveform for an open-circuit fault of 75 m cable is shown in Fig.5- 9.

It can be known the reflection signal has some certain attenuation in the amplitude, with the time delay compared with the reference or probe signal. Through correlation algorithm, the normalized correlation waveform is obtained in Fig. 5-9 (B). The estimated time of the first peak, which is the reference signal itself, is 5.423 $n_s$, while the estimated time of the second peak (cross-correlation of the reference signal and the reflected signal) is about 7.143 $n_s$. With the signal velocity of propagation on the cable ($v_p$=0.6 m/sec), the location of the fault can be estimated to be 75 m distance. While the second reflected peak is right-side-up, so it is diagnosed with an open-circuit fault type.

**Parameters used for SSTDR mathematical analysis and simulation**

- $f_s$ = 100: where $F_s$ signal frequency (Incident)
- $f_c$ = 100: where $f_c$- is carrier frequency
- Total distance = 1000m = 1km
- Reflection(amplitude) α→ coefficient
- $\alpha_1$= 0.25 $\alpha_2$= 0.25 $\alpha_3$=0.5 $\alpha_4$=1




- $L_1$=250m
- $L_2$=500m
- $L_3$=750m
- $L_4$=1000m=1k

: Reflection coefficients are randomly given for simulation purpose at different reflection distance

| | i=1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $L$ | 0.25ι | 0.5ι | 0.75ι | 1ι |
| α | 0.25 | -0.25 | 0.5 | 1 |
| $\tau_i$ | 2.381 $n_s$ | 4.76 $n_s$ | 7.143 $n_s$ | 9.513 $n_s$ |

Table 5-2: parameters and coefficient of sample measured

Where time delay ($\tau_i$) at each reference point is:

- $\tau_1 = 2.381\ n_s$
- $\tau_2 = 4.76\ n_s$
- $\tau_3 = 7.143\ n_s$
- $\tau_4 = 9.513\ n_s$

**NB:** Measured for 1000m or 1Km distance

Threshold value of the reflected signal will be

- Power used: 0.5 mv for open circuit and -0.5 for short circuit reflection or inverted reflection.
- Noise used for simulation: Gaussian Noise Generator

Distance of fault location can be determined by:

$\varphi = {}^{1}/_{2} * v_p * c$ and $l = \varphi * \tau$ Where c: speed of light $l$: is distance of fault or reflection point $\tau$:is transmission time delay $V_p$ = 0.6 = velocity of the transmission line

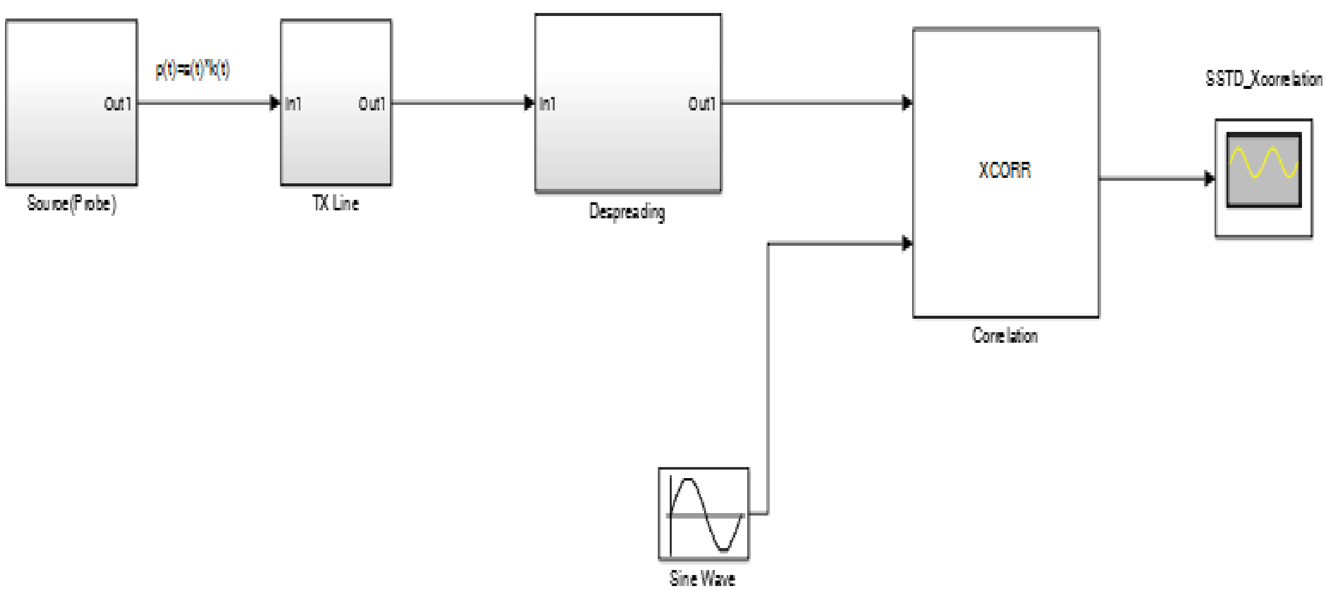



Figure5-4: Simulink modelling block diagram

Source or Probe f(t): is a combination of sin wave *S(t)* and sequence generator which is Kasami sequence generator in this case represented by *K(t).*

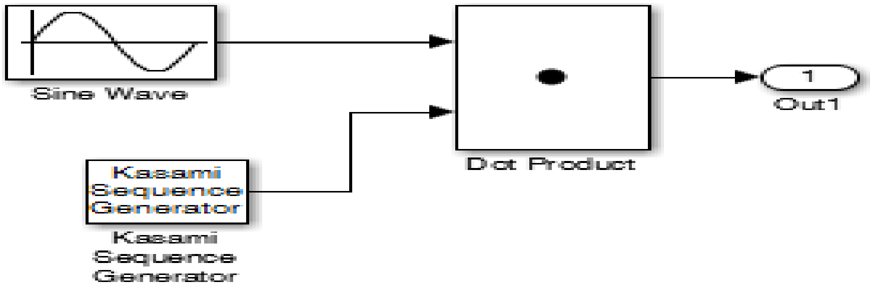



Figure 5-5(A): probe/source signal & Despreaded signal

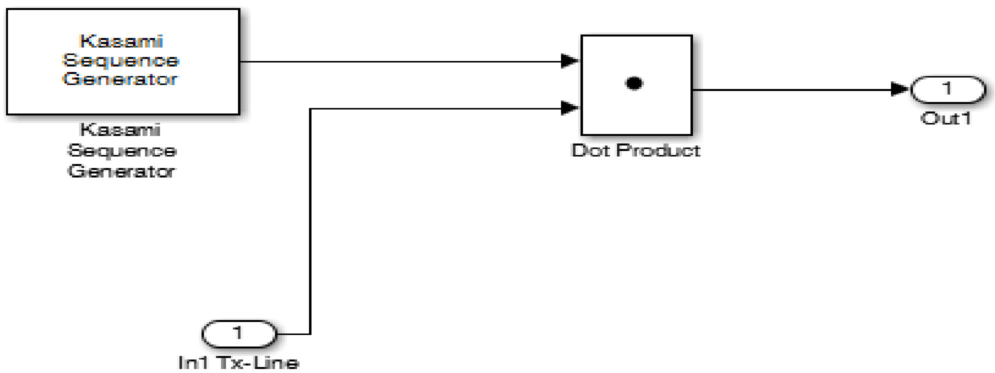



Figure 5-5(B): probe/source signal & Despreaded signal

Form the above Figure 5-5 Simulink blocks signal is De-spreaded by injecting sequence generator →kasami-K(t) over the transmission line signal.

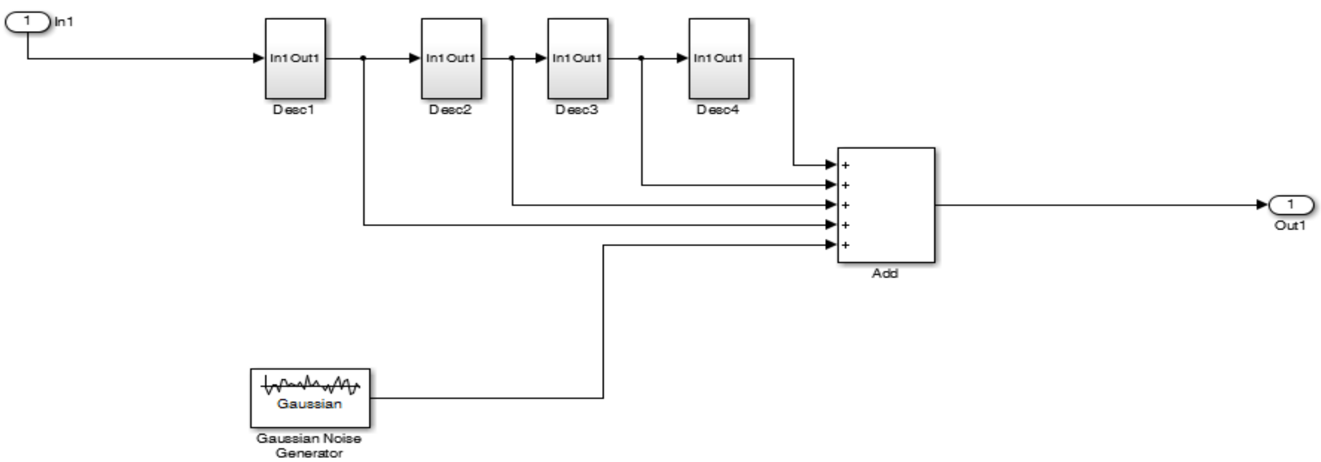



Figure5-6: Transmission line added with noise

From the above Simulink model sum of different incident points added with Gaussian noise and will be input /injected to correlation blocks. Minimum threshold value of reflected signal to be determined as either open or short fault will be 0.5 mv for open circuit and 0.5 for short circuit reflection or inverted reflection.

## 5.2 Result and Analysis:

### Scenario I: Simulation Result

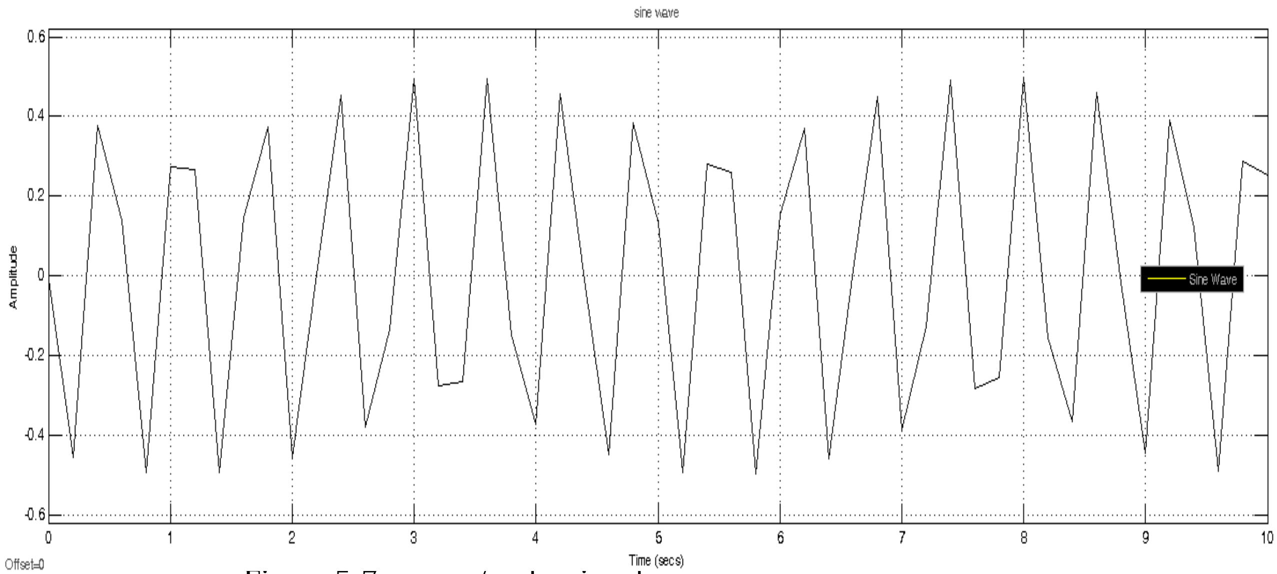



Figure 5-7: source/probe signal

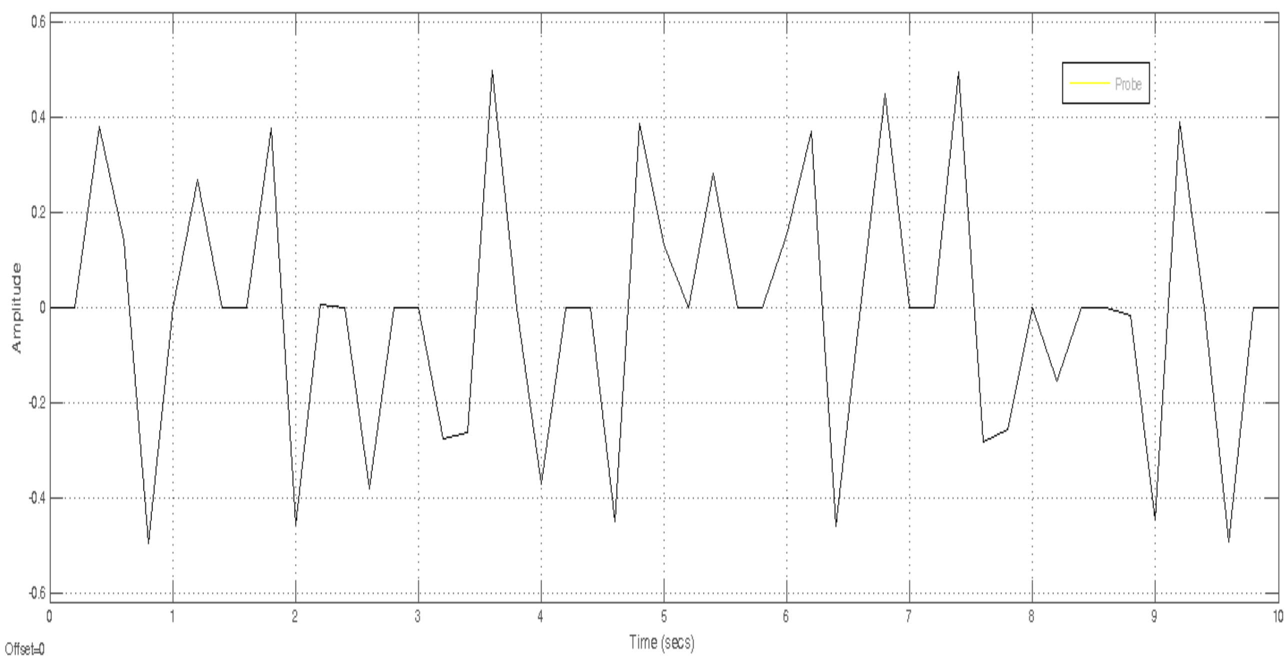



Fig 5-8: SSTDR reflection simulation result

From the above Figure 5-8 reflection signal: Output of input signal and sequence generator (sine wave + Kasami sequence generator). The above reflection output is after source signal or probe signal is modulated with kasami sequence generator.

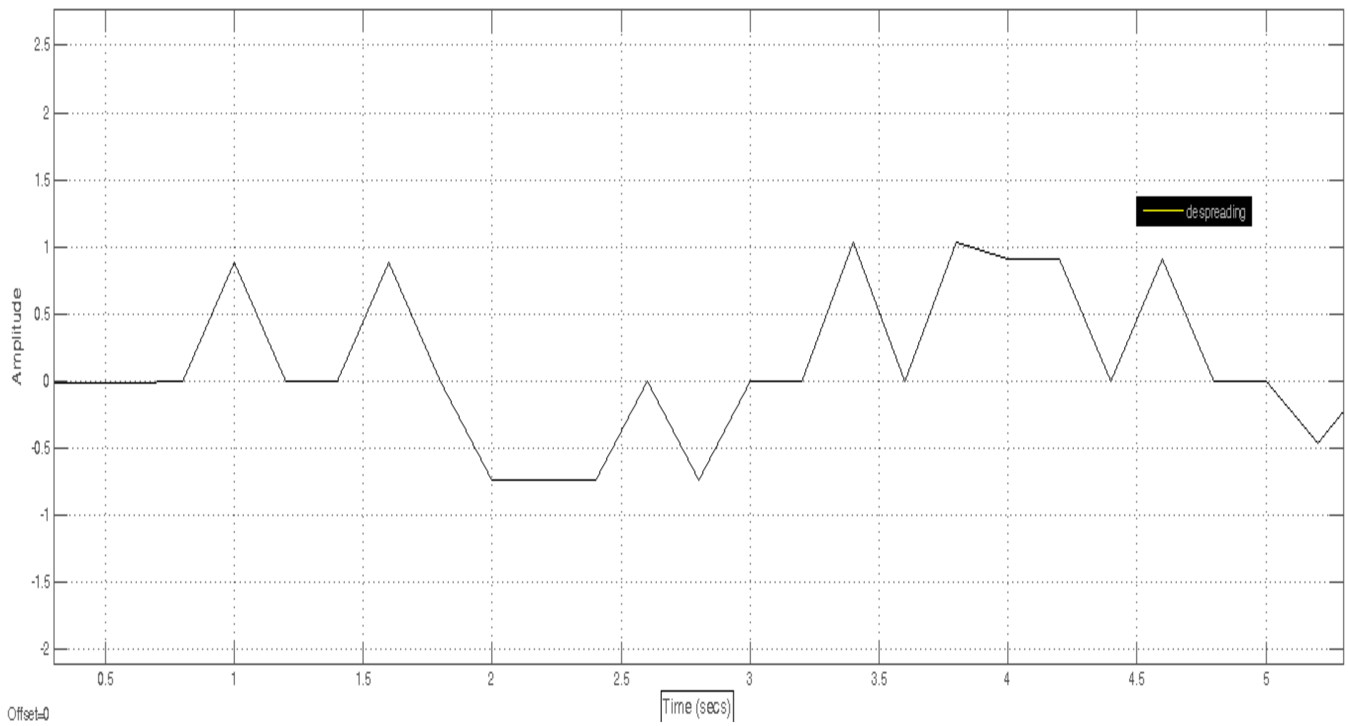



Figure 5-9(A): Reflection signal after spreaded over transmission line

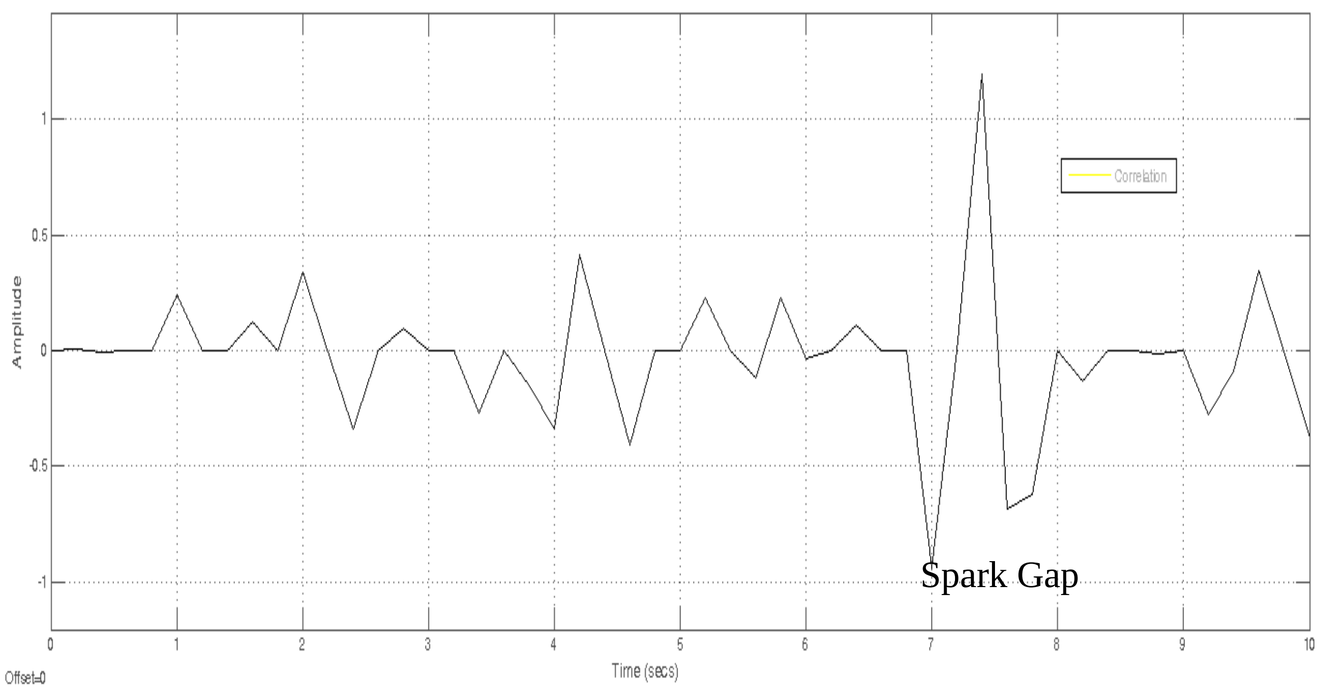



Figure 5-9 (B): Reflected signal after correlation/output

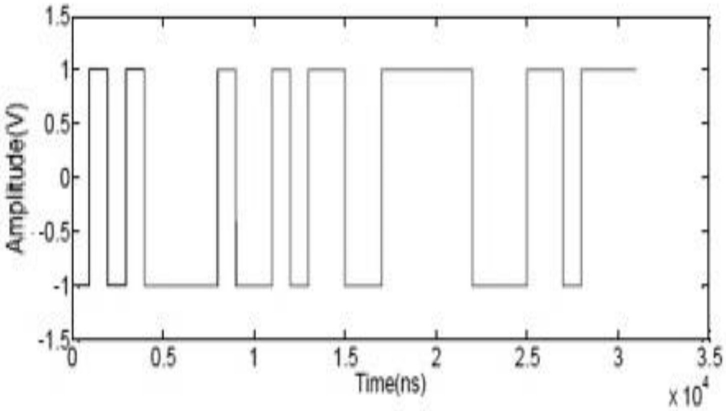
The desired output or reflection signal achieved after spreading/dispreading and cross correlation has been processed.

From the above Simulation result incident signal and sequence generator (kasami sequence generator) is introduced to the transmission channel and spread over the lines with additive noise which is AWGN and then despreaded before cross correlation is done, finally the cross correlation will be reflected at certain distance point with intermittent or distortion noise. Delay to acquire the desired reflection signal and the type of the reflection will determine the type of the fault. From the above model/scenario the fault is open circuit at about 75 m distance when evaluated using.

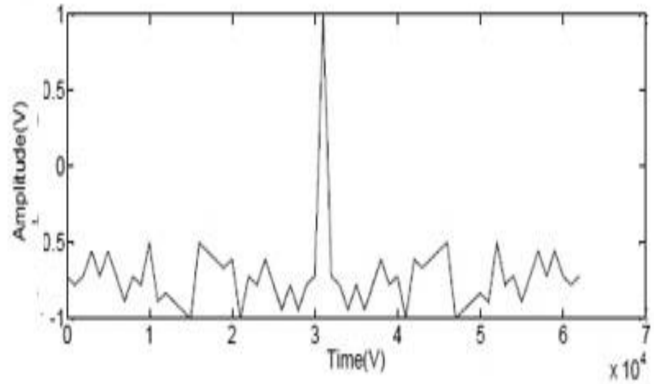
$\varphi = {}^{1}/_{2 * v_p} * c$ and $l = \varphi * \tau$ Where $v_p$ is speed across the cable i.e 0.6 & $c = 3 * 10^8\ m/s^2$ speed of light $\tau_i$= transmission time delay

In general, from the above signal reflection and analysis from the simulation results, SSTDR perform better fault detection with minimum calibrated signal amplitude and power relative to the classical TDR fault detection with better location accuracy. For further analysis and demonstration using below simulation result which accommodate modulation techniques with the same scenario to the above Simulink output using cross correlation algorithm for the incident signal and reflected signal will be. In this study comparison analysis and demonstration were done as it can be seen in table 5-3/4 and figure 5-11/12 with respect to their signal to noise ratio and distance accuracy for both the classical TDR and SSTDR fault detection.

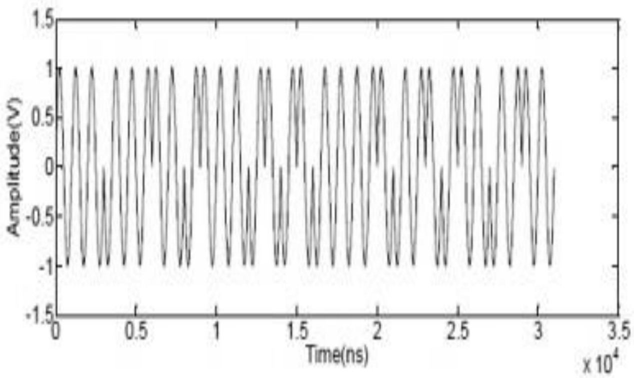
## **Scenario-II:** Sample for SSTDR fault detection reflection



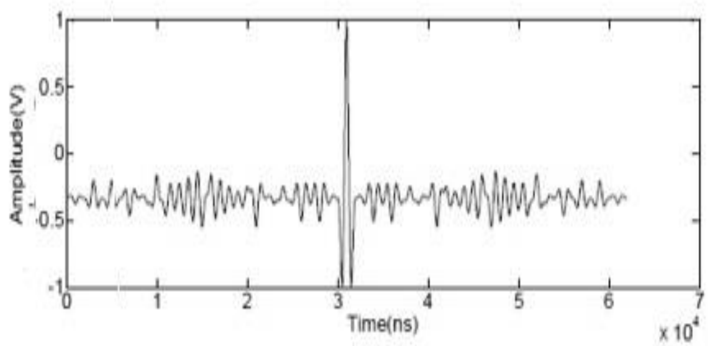

Sequence generator simulation waveform



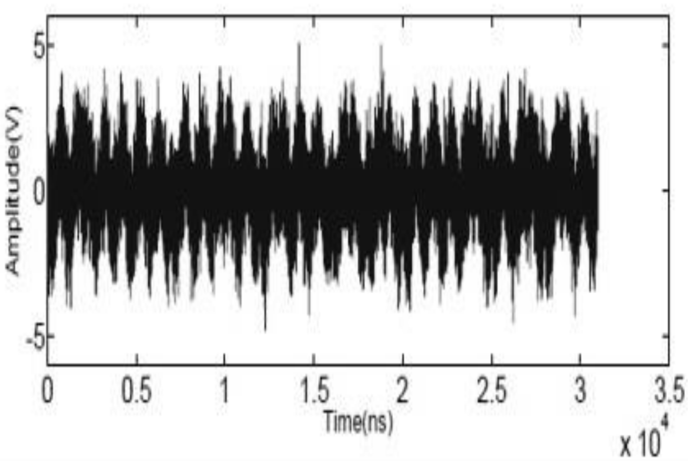

Normalized autocorrelation of Sequence generator



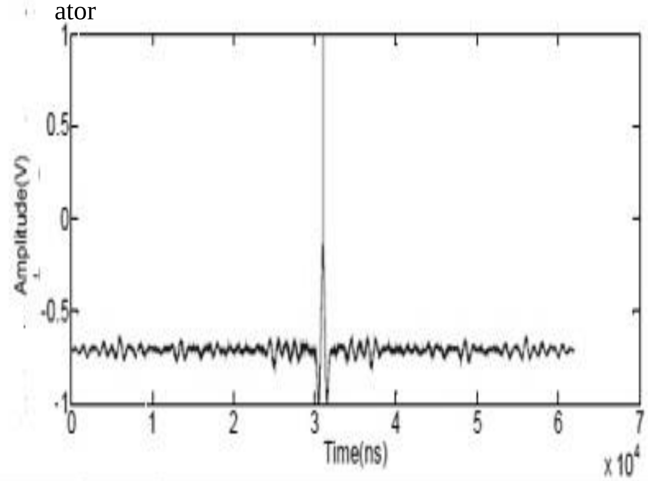

Modulated Sequence generator simulation waveform




Normalized autocorrelation modulated Sequence generator




SSTDR test signal interfaced by PN noise




Normalized autocorrelation of SSTDR signal interfaced by PN Sequence generator

Figure5-10: Test signal wave form for SSTDR fault detection

## 5.3 Result Comparison and Verification for Distance Measured and Error Detected Using TDR & SSTDR Technique

Comparison of classical TDR and distributed SSTDR method estimates of fault location for different fault locations, and types of fault generated during twisted pair cable test.

| Length/ distance | Fault type | TDR fault location and error rate | | SSTDR fault location and error rate | |
|---|---|---|---|---|---|
| | | length | error | length | error |
| 50m | damage | 49.37 | 0.63 | 49.74 | 0.26 |
| | Open | 49.26 | 0.74 | 49.64 | 0.26 |
| | short | 49.37 | 0.63 | 49.85 | 0.15 |
| 30m | damage | 29.51 | 0.49 | 29.76 | 0.24 |
| | Open | 29.41 | 0.59 | 29.72 | 0.28 |
| | short | 29.48 | 0.52 | 29.77 | 0.23 |
| 20m | damage | 19.58 | 0.42 | 19.90 | 0.10 |
| | Open | 19.47 | 0.53 | 19.87 | 0.10 |
| | short | 19.58 | 0.42 | 19.87 | 0.13 |
| 10m | damage | 9.51 | 0.49 | 9.91 | 0.09 |
| | Open | 9.62 | 0.38 | 9.89 | 0.11 |
| | short | 9.62 | 0.38 | 9.90 | 0.10 |

Table5-3: physical distance location of faults

The errors for TDR are between 0.4% and 0.8% while the errors of SSTDR are under 0.4% for all cases. Therefore, the classic TDR has shown greater error rate increasing with distance than SSTDR.

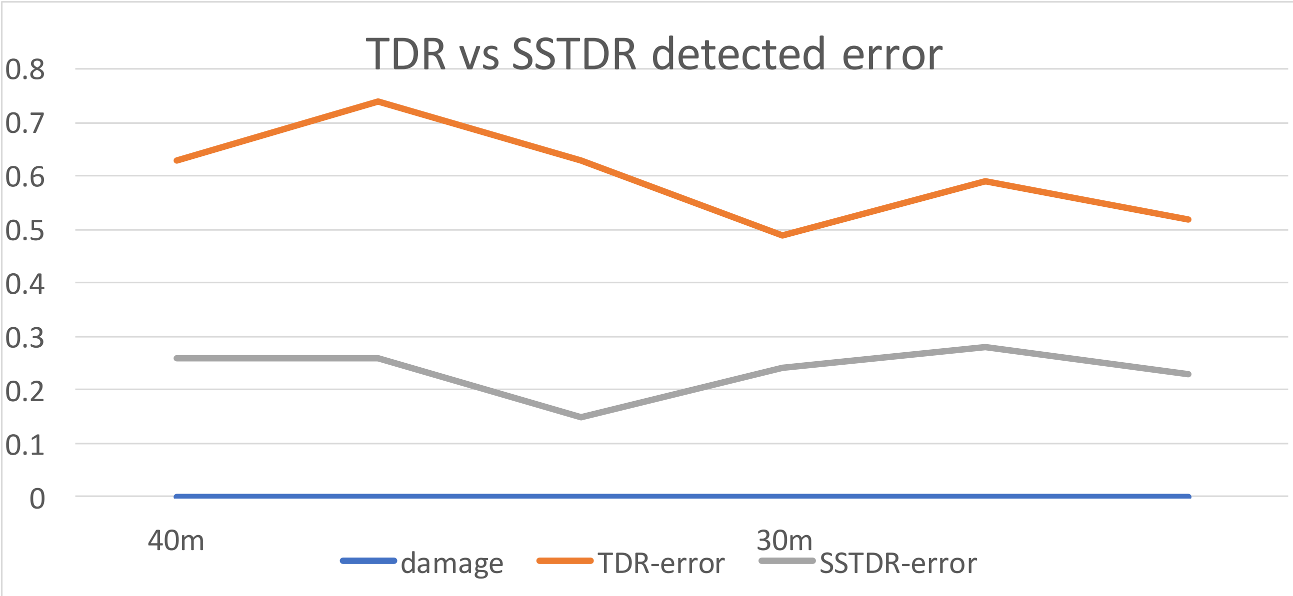



Figure 5-11: chart for TDR vs SSTDR detected error

Hence the fundamental advantage of SSTDR fault detection is enhancing the SNR of the transmission line as it can be observed in below analysis for certain threshold value of SNR the fault detection error of SSTDR is smaller than TDR which implies SSTDR fault detection has greater accuracy than TDR.

Signal to noise ratio can be defined: $SNR = 10\log_{10}(signal\ power/noise\ power)\ dB$

Whereas the signal power is the threshold value used i.e. 0.5 mv and noise power is the noise at each reflection point.

SNR vs detection noise power of TDR & SSTDR

| SNR | Detection error in TDR | Detection error in SSTDR |
|---|---|---|
| -5: 0 | 0.0775 | 0.0649 |
| 0: 5 | 0.0687 | 0.0642 |
| 5: 10 | 0.0735 | 0.0727 |

Table 5-4: SNR vs detection noise power of SSTDR and TDR

From the mathematical analysis results, it is observed that the detection error is minimum for SSTDR and maximum for TDR. The below graph shows noise power of SSTDR and TDR.

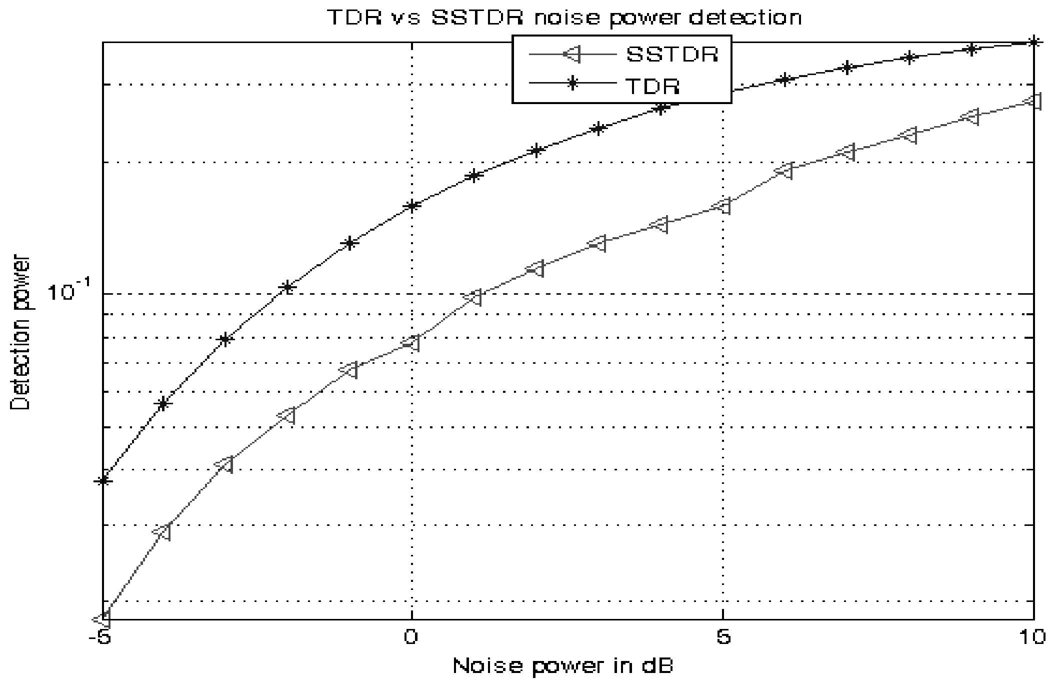



Figure 5-12: detection power vs noise power for TDR & SSTDR

In general, from hand mathematical calculation and research simulation result the proposed fault detection technique can be verified within three basic parameters those are location of the reflection point that is a spot for the fault, power optimization and reduction and its accuracy on detecting error or it is nearest to the exact location than the classic TDR detection techniques.

6

# CHAPTER SIX: CONCLUSION AND FUTURE WORK

## *6.1* Conclusion

This study suggested a method to detect cable faults in a distorted connection state to overcome poor contact fault in advance. Loose and distorted connection is considered as a soft fault that is difficult to differentiate, compared to other physically visible faults such as disconnection (open circuit) or short circuits. For this reason, this study proved through experiments and simulation how the bad contact fault can be detected at different reflection points and nodes. In addition, a suitable SSTDR according to the state of the cable either live or dead was selected and the detection accuracy of reflection signal returning from the fault point was improved by applying an incident signal correlation algorithm. The accuracy of the detection was shown by checking the fault specific location and error rate of the detected signal. As a result of such experiments, in a loose and bad connection condition caused by a decreased compression at a faulty wire state, detecting problematic faults either poor(bad) contact fault or disconnection(open) fault that may occur concurrently in a single cable was possible at the connection of rotating force using SSTDR detection technique.

In this thesis, short and open circuit faults are detected in a better performance and accuracy, using the proposed method of Distributed system the so called spread spectrum time domain reflectometry(SSTDR). The sequence generator (Kasami sequence generator), modulated by the sine wave, with the features of sharp correlation reflection and high resistance of noise, was selected as test signal.

The experimental results proved the feasibility of SSTDR for ADSL cable or transmission line fault detection. Moreover, SSTDR will play the more and more crucial role in detecting faults in future, especially, in ADSL digital cable fault detection area. The lowest or minimal test signal levels or equalizes and high noise and interference immunity of these test methods make them well matched to test for irregular or distorted wiring and connectivity failures and the fault could be open circuits, short circuits, and discontinuity at certain nodes.

Based on the simulation results have in Chapter 5; we conclude the following.

- Spread spectrum time domain algorithm have advantages in fault detection performance compared to the classical Time Domain Reflectometry fault detection techniques by several parameters.
- Spread spectrum time domain reflectometry with special code algorithm performs better than Time Domain Reflectometry fault detection system with improved fault location accuracy and to exactly determine fault type.
- As one can see clearly from the above table-5.4 and in figure 5-12, we can achieve small error rate using SSTDR fault detection method.
- By comparing figure 5-9 and 5-10, we can say that SSTDR fault detection method gives better detection performance, channel capacity with greater SNR as compared to the old classical TDR fault detection method.
- We see that comparing the cooperation and point-to-point transmission, the latter (SSTDR) is good in terms of spectral efficiency and reliability and not good in terms of complexity of detection system, whereas the former (classical TDR) is not good in terms of reliability, scalability, detection accuracy and good in terms of operational simplicity.

Previously several cable troubleshooting methods have been studied and developed in different scenario for the past decades, and showing great performances with their own limitations. One of the fundamental limitation and problem is the identifying and locating of very long distance cables, which can be found in wire infrastructures constraint, signal attenuation and distribution prevent from accurately locating defects of the wire.

A second challenge and limitation or problem is the management of propagation similarity. A real or ideal cable is never 100% similar. The coil or twist of a twisted pair is not perfectly the same along the transmission cable, and even a high-quality transmission line pair cable is not necessarily similar. Such un similarity or impurity can be mistaken by a reflectometer as soft loose defects. Time setback principles can be used to enhance simple faults or soft defects detection, but a new method called SSTDR detection approach offers new perception for this type of problem. It can characterize itself to the signal type and adjusted to the network under test, thus propagating information about the un similarity and impurity. This SSTDR proposed technique signal helps to avoid the impact or influence of the cable itself and focus on the defect points.

Another interesting application of SSTDR is its topology reform and the use of optimization methods. It looks thinkable to give the accurate location of any type of fault especially hard type of defect inside.

In this paper the need for cable diagnosis and troubleshooting in various application area and presented the theoretical bases of SSTDR based methods is exposed. The important problem of soft or loose defect detection has been emphasized and explained, and some new solutions have been presented.

In general, this thesis focuses on the adoption and implementation of SSTDR fault detection by modulating the sine wave with kasami sequence generator as incident signal and spreaded over the transmission line within reasonable energy or power threshold and de-spreaded again before cross correlation is done and a peak signal formulated will determine the type of fault and the location of fault is also determined by considering the incident signal and the reflected signal by time delay.

## 6.2 Research Recommendation for Future Work

This research is another significant step towards understanding the concept and importance of optimization and detection studies between different types of ADSL transmission line and design and setup of spread spectrum time domain reflectometry or distributed system that help in making the decision of what types of fault is occurred.

1. The monitoring of the faults influencing the transmission line or cable and optimization process between the SSTDR and TDR bridges should be continued.
2. Hopefully, with future researches, the dependability of optimization studies as an effective decision maker procedure in the preliminary design stage will be verified loading to an increase in the cost effectiveness, detection accuracy, ease of manipulation and improvement of the algorithm appearance criteria for fault detection.
3. Attention to studies related to the algorithm of SSTDR and choosing the type fault detection method.
4. Use of ready software to assist in the analysis and design of bridges like (MATLAB, Java, C#, C) process in the course to highly automate.
5. Recommend to analyze SSTDR for ADSL transmission line research using different filtering techniques and algorithms.

# BIBLIOGRAPHY


[1]. ITU-T Recommendation G.992.3, Asymmetric Digital Subscriber Line transceivers 2 (ADSL2).

[2]. Broadband internet access 13. March 20, Available: https://fas.org/sgp/crs/misc/RL30719.pdf

[3]. Furse, C., Chung, Y.C., Dangol, R., Nielsen, M., Mabey, G., and Woodward, R.,"Frequency Domain Reflectometry for on-Board Testing of Aging Aircraft Wiring," IEEE Transactions on Electromagnetic Compatibility, Vol. 45, No.2, pp. 306-315, May 2003.

[4]. Smith, P., Furse, C., and Gunther, J.,"Analysis of Spread Spectrum Time Domain Reflectometry for Wire Fault Location," IEEE Sensors Journal, Vol. 5, No. 6, pp. 1469-1478, December 2005.

[5]. John Ross, Telecommunication Technologies, Voice Data & Fiber-Optic Applications, Sam's Technical-Publishing,2001.available:https://www.sciencedirect.com/topics/computer-science/twisted-pair-cable& https://networkencyclopedia.com/shielded-twisted-pair-stp-cabling/

[6]. DSL Forum, SHDSL FAQ ,Available: http://www.dslforum.org/aboutdsl/shdsl_faq.html.

[7]. Feasibility of SSTDR for Identifying Electrochemical Signatures of Degradation PDRA Presentation Name: Musbahu Muhammad WP:3 Institution: Newcastle University Elza. s.l.: IEEE Wireless Communications and Networking, 2003.

[8]. Advanced Interference Suppression Techniques for Spread Spectrum Systems Symposium on Information Theory, 2002. p. 220, Progress in Electromagnetics Research B, Vol. 49, 2013

[9]. Spread-space spread-spectrum technique for secure multiplexing B. M. Hennelly, T. J. Naughton, and J. McDonald,2009, The performance analysis of cooperative space time coded systems. L.chu, J. Yuan. s.l.: Vehicular Technology Conference, IEEE65th, 2007.

[10]. Analysis of Spread Spectrum Time Domain Reflectometry for Wire Fault Location Paul Smith, Member, IEEE, Cynthia Furse, Senior Member, IEEE, and Jacob Gunther, Member.

[11]. Fault Detection of Aircraft Cable via Spread Spectrum Time Domain Reflectometry 1, 2 Xudong SHI, 3 Xiaohui LI, 3 Zhangang YANG.

[12]. Time domain reflectometry measurement principles and applications Scott B. Jones,1* Jon M. Wraith2 and Dani Or1.

[13]. Time domain reflectometry for electric power cable diagnostics 1J. Suganthi, M.E., 2G,2009.

Nithya, M.E.3S.Prakash, M.E.,4N.P. Gopinath, M.E.

[14]. Regis J. Bates, Broadband Telecommunications Handbook, 2nd Edition, McGraw-Hill, 2002.

[15]. Channel estimation and on-line diagnosis of LV distribution cabling César Picos Hernández.

[16]. Layane Abboud. Time Reversal techniques applied to wire fault detection and location in wire net works. Other.Supélec, 2012.English. https://tel.archives-ouvertes.fr/tel-00771964.

[17]. S. Androulidakis, D. Kagklis, T. Doukoglou and S. Skenter, "ADSL2 against SHDSL for sym metric broadband access networking", Electronic Letters,vol. 40, Issue 16, pp. 1027-1028, Aug 2004.

[18]. Available:https://www.viperinnovations.com/wp-content/uploads/5302 139097_R02_SSTDR_Flyer

[19]. Available: https://www.exfo.com/en/resources/blog/simplifying-resistive-fault-location/

[20]. Digital-Subscriber-Line, 7-March-2007, Available: https://www.slideshare.net/PoonamSarawgi/underground-cables-59620842

[21]. John Ross, Telecommunication Technologies, Voice Data & Fiber-Optic Applications, Sam's Technical-Publishing,2001.

[22]. DSL-Forum, SHDSL-FAQ and See ITU Recommendations ITU-T G.992.3 and ITU-T 992.4 at: http://www.itu.int/rec/recommendation.asp?type=folders&lang=e&parent=T-RECG.992.3/4

[23]. Regis J. Bates, Broadband Telecommunications https://EzineArticles.com/expert/RajshreeKP./344840

[24]. Available: https://www.edpnet.be/en/support/my- endpnet/how-to-interpret-line-test-results.html.

[25]. Norsworthy, R. 1998. "Coating proves effective on hot oil pipelines." Pipeline and Gas Journal, March.

[26]. A. Hamel, A. Gaudreau, and M. Cote, "Intermittent arcing fault on underground low-voltage ca bles", IEEE Transactions on Power Delivery, vol. 19, pp. 1862-1868, Oct. 2004.

[27]. Available:https://www.scribd.com/document/157387050/Cable Fault Monitoring and Indication Review

A

# APPENDIX

## A.1 Reflection of Detected Signal & Results

### Scenario I: Simulation Result

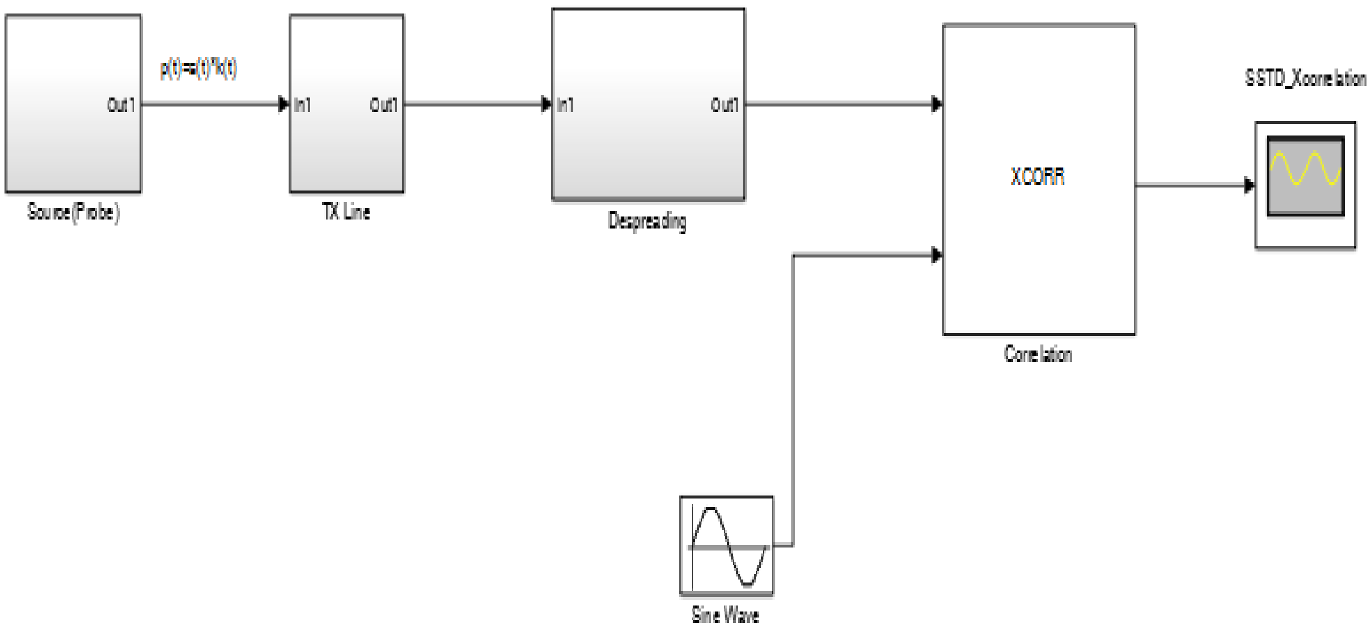



Figure A-1: SSTDR algorithm process & Diagram of SSTDR cable fault detection for ADSL using Simulink

### Output of Reflected Signal for different fault type

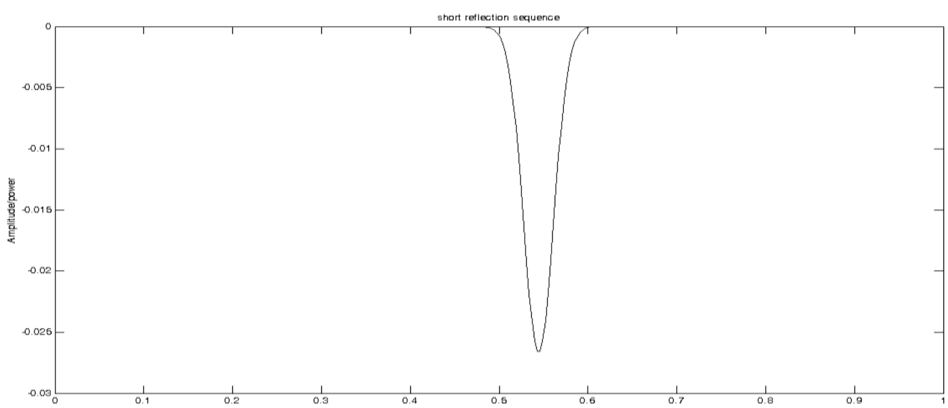



Figure A-2: Reflected signal for short circuit fault type since $R_{sr}<0$ or impedance is ve

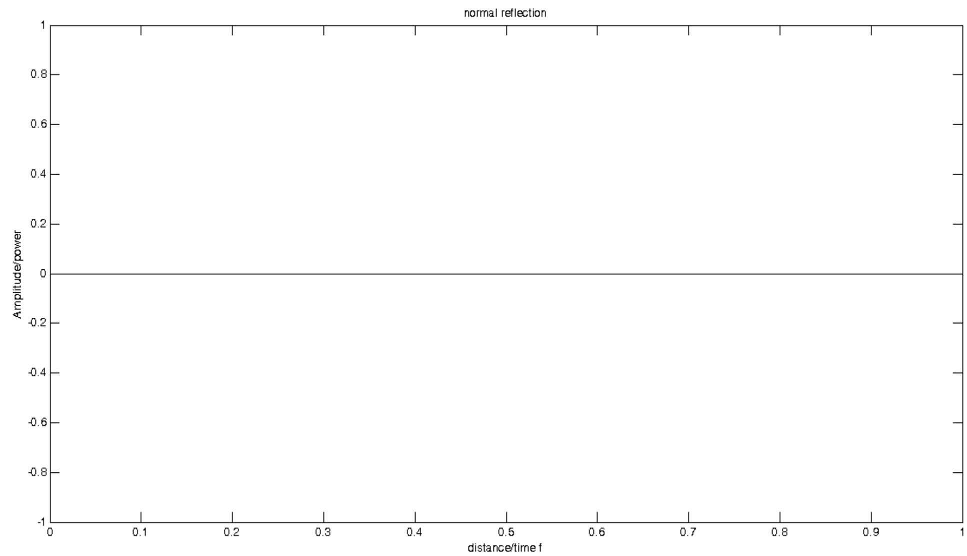



Figure A-3: Reflected signal for Normal circuit fault type since $R_{sr}$=0 or impedance is zero

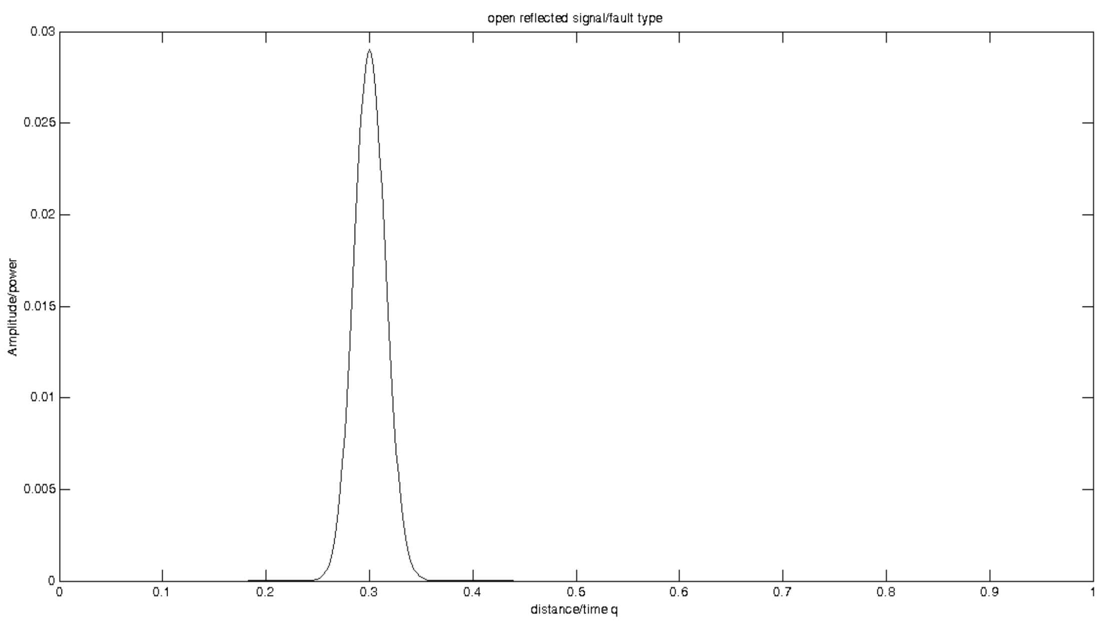



Figure A-4: Reflected signal for Open circuit fault type since $R_{sr}$ >0 or impedance is +ve

## Scenario-II: Signal Analysis & Reflection using Matlab code/file

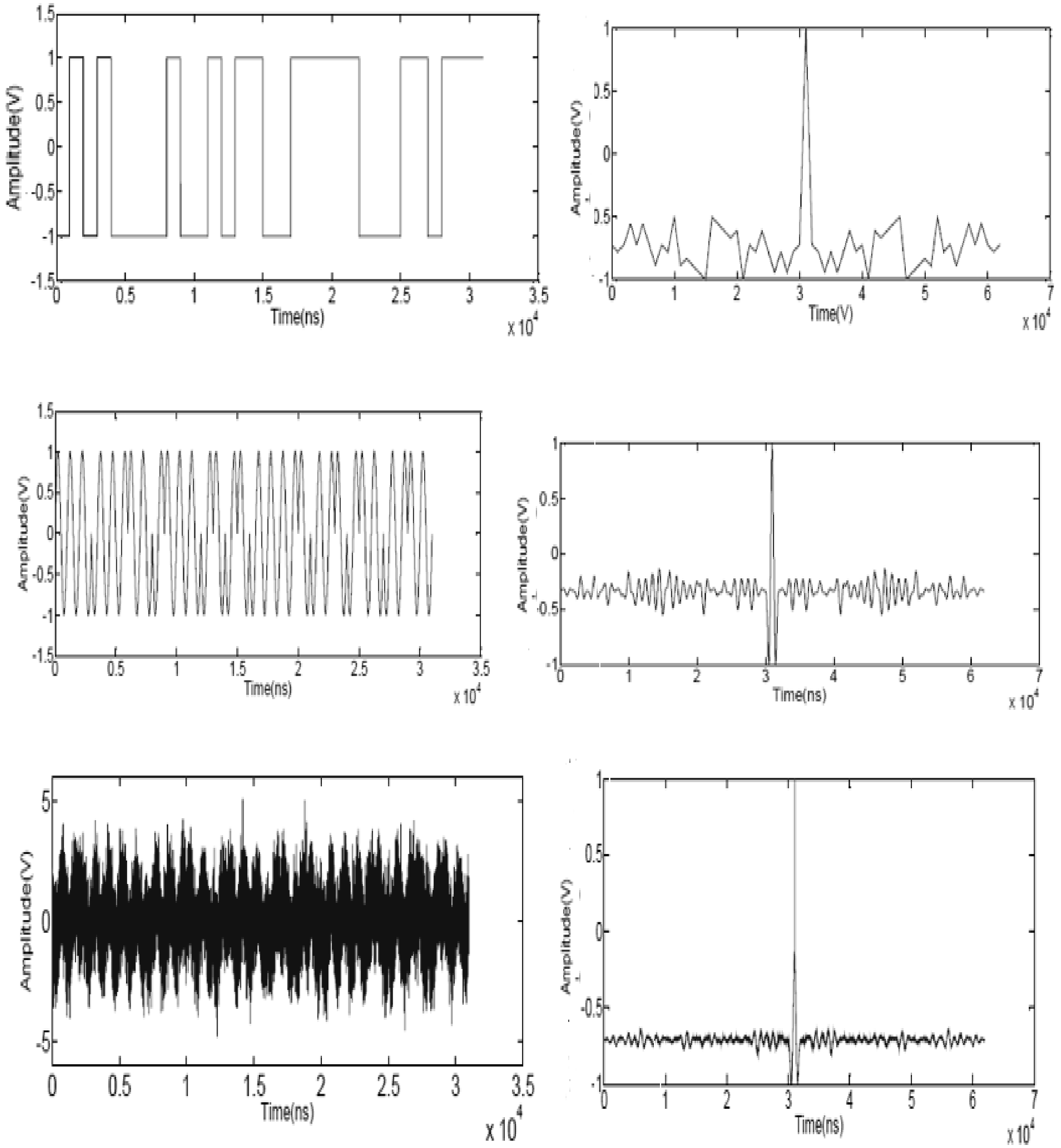



Figure A-5: SSTDR wave form /Reflection

## A.2 Transmission Chanel Detection Model

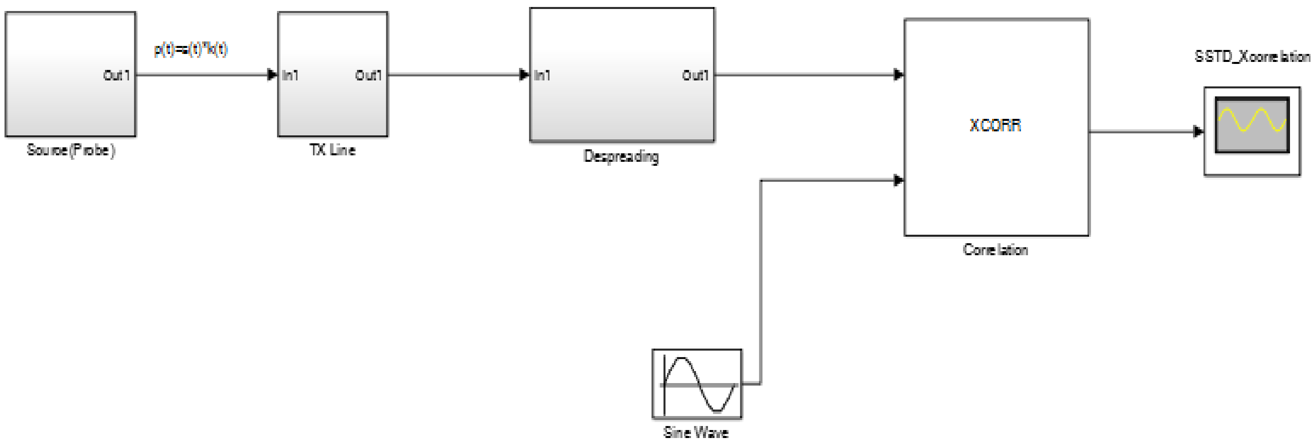



Figure A-2/1: SSTDR algorithm process & diagram of SSTDR cable fault detection for ADSL using Simulink

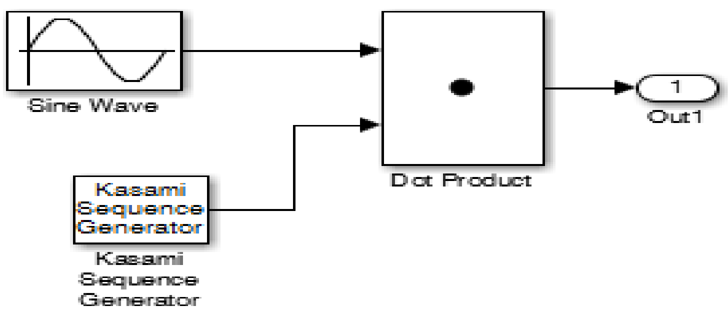



Figure A-2/2: probe/source signal & spreaded signal

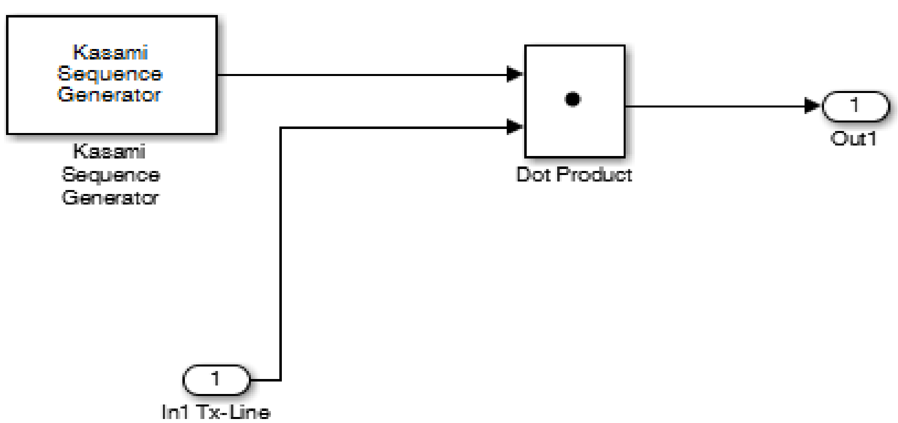



Figure A-2/3: probe/source signal & Despreaded signal

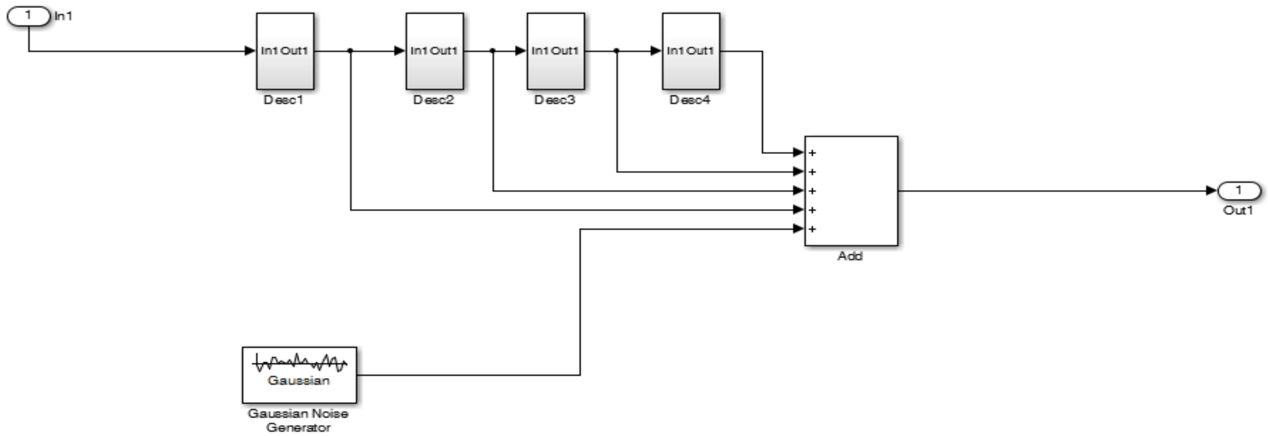



Figure A-2/4: Transmission line added with noise

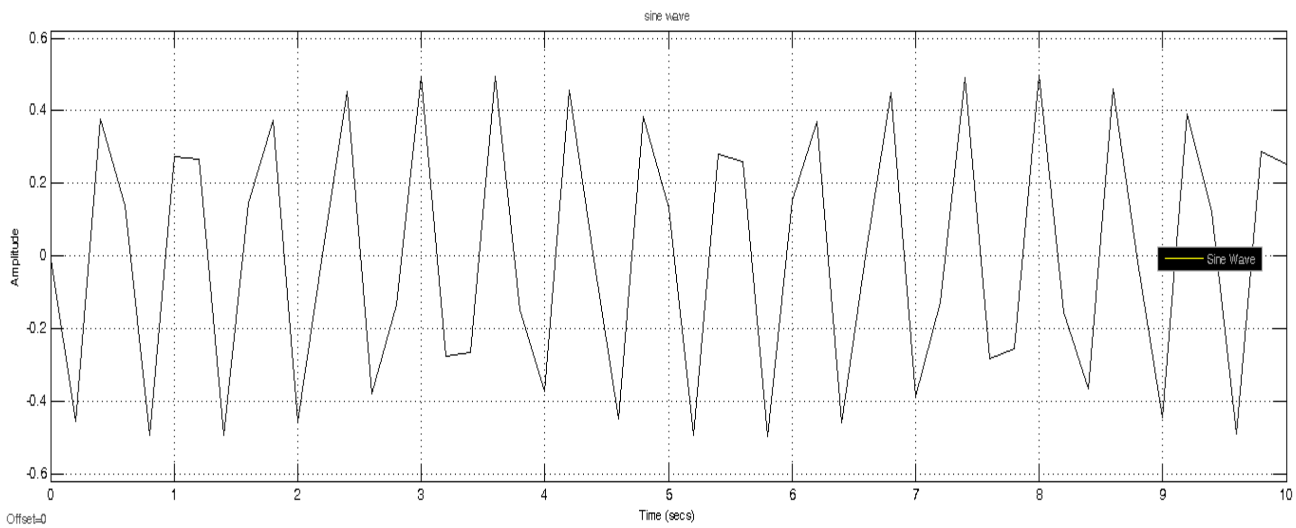



Figure A-2/5: source/probe signal

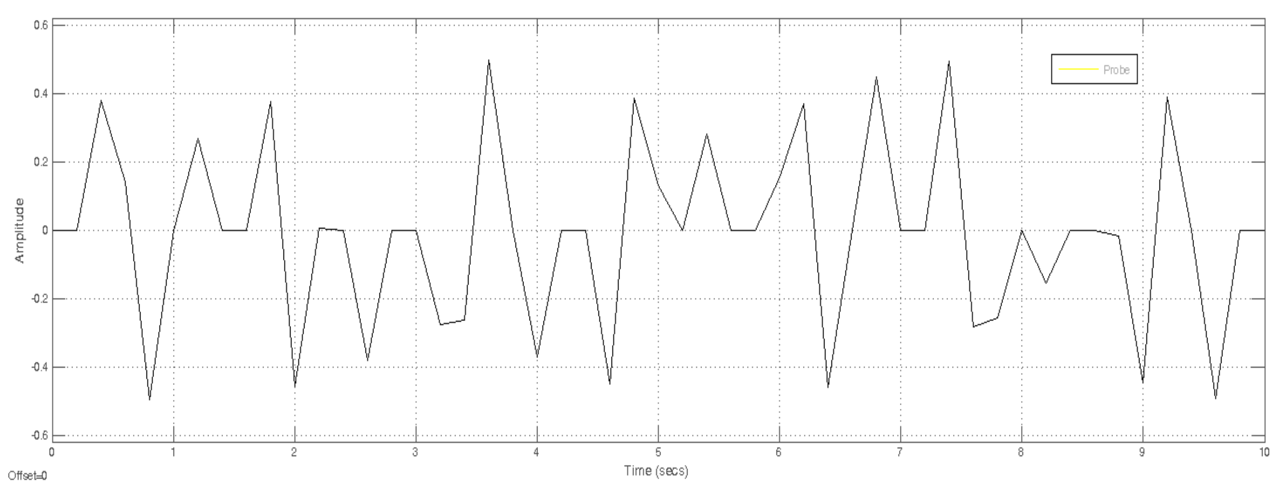



Figure A-2/6: SSTDR reflection simulation result/sequence generator modulated with sine wave

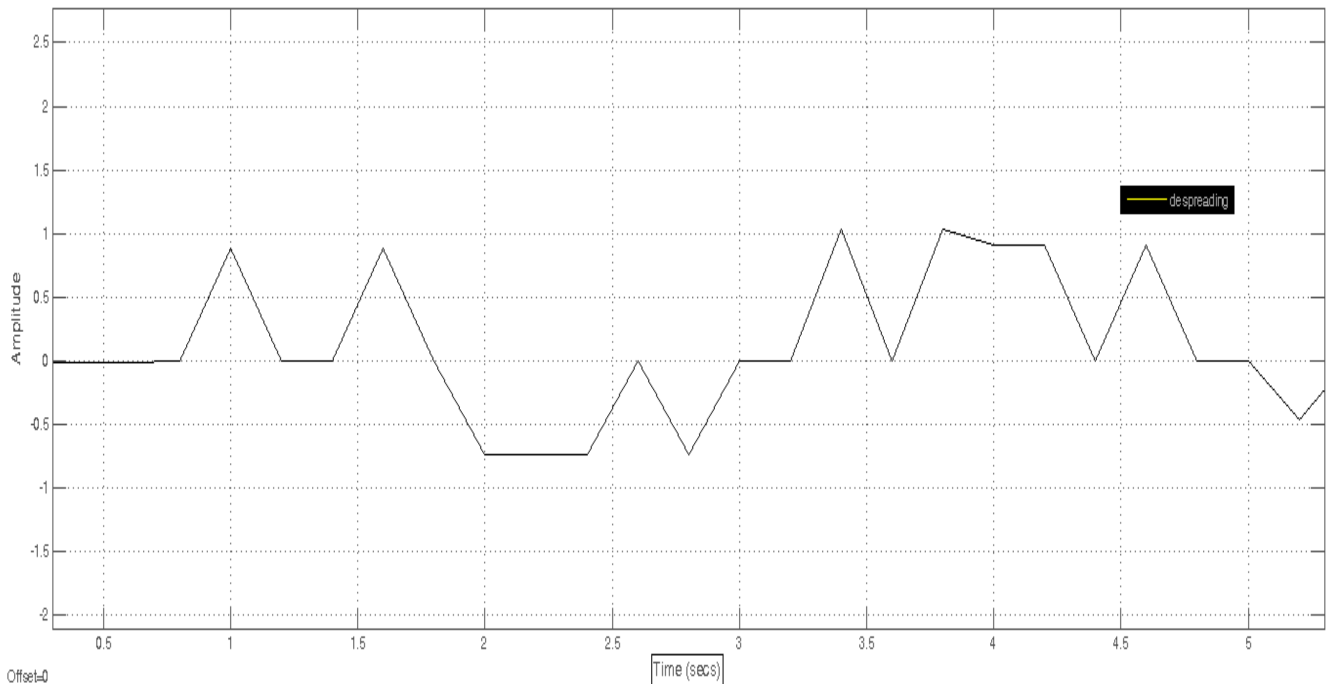


Figure A-2/7: Reflection signal after speeded over transmission line

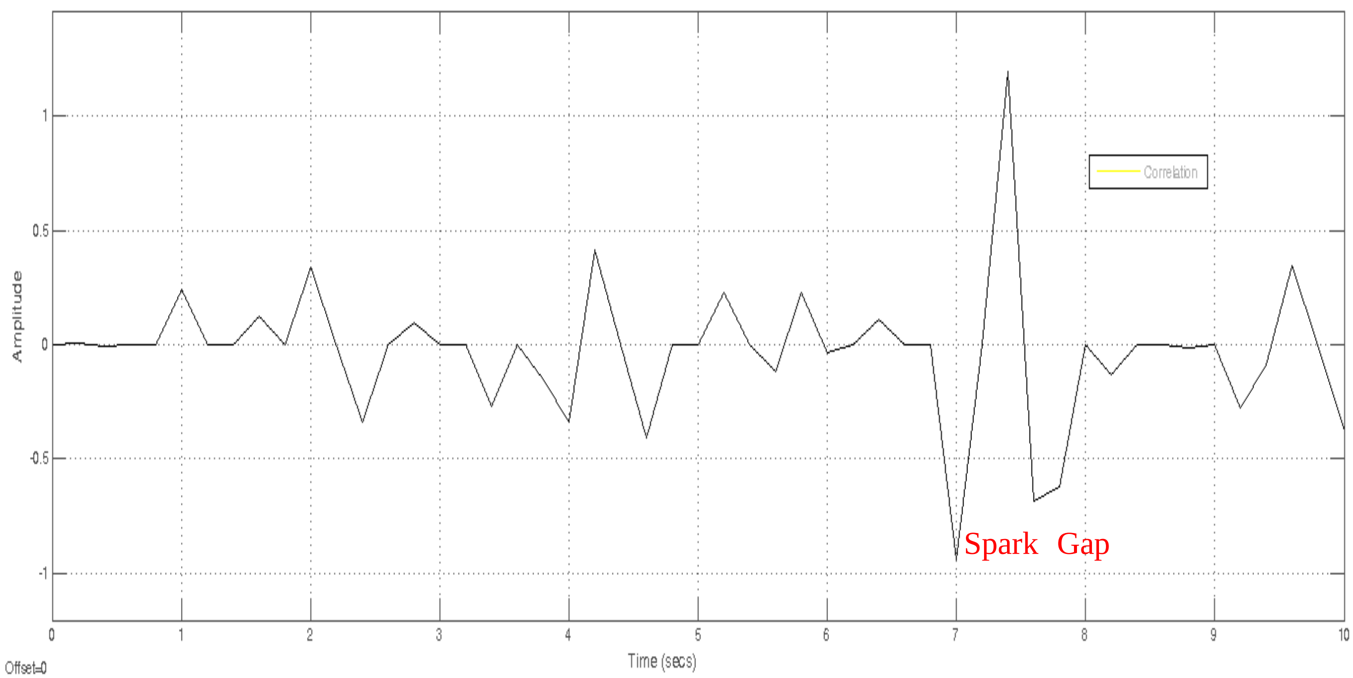


Figure A-2/8: Reflected signal after correlation/output

## SSTDR Operation and Analysis of the Findings

• Outputs or reflected signal retransmitted to the source with fast voltage over channel,

• Get voltage at source or probe side, which includes reflections of the signal at the incident point

• The amount of Voltage magnitude could be converted to resistance or impedance and analyzed the reflections signal,

• Impedance mismatch and electromagnetic discontinuity location can be determined by time delay

From the source/probe side sequence generator modulated with sine wave is consecutively injected to the transmission line and the transmission line incorporated with noise(AWGN) is spreaded over the test line and despreaded before correlation take place, then the incident and the reflected signal will be correlated, finally reflection of signal will be appearing based on the magnitude and the direction of the reflected signal, then reflected signal will be determining type of fault. However, SSTDR correlates the reflection to associate alongside the transmitted signal to make an arbitrary a waveform. The SSTDR loose detection algorithms are then applied in order to identify fault type and offer a location information to the user or fault detector without the need for interpretation. Isolate faulted sections using spread spectrum technology over the existing TDR techniques which locate and interpret cable faults and verify integrity of cable insulation.

In general, it has been verified that distributed reflectometry technique called SSTDR has the high tolerance or immunity of noise, minimizing some fault detection errors effectively and is considered to be an operative method to detect irregular faults and discontinuity such as open circuits and short circuits. Theoretically, the test signal from probe has the higher immunity and resistance of noise, which can be practical with better precision to fault location on the different cable. SSTDR fault detection technique in case of ADSL technology was analyzed and comparison were done with the existing classical TDR fault detection. The parameter used for comparisons are: error detection ability, signal to noise ratio and fault location or distance identification accuracy are basic parameter’s used for verification. So, from this essential parameter’s perspective SSTDR shown improvement compared to the existing classical TDR fault detection technique.