IOT Application in DUT High Frequency Measurement

by

Chong Yi Chuan
18049

Dissertation submitted in
partial fulfilment of the
requirements for the

Bachelor of Engineering
(Hons) (Electrical and
Electronics)

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CERTIFICATION OF APPROVAL

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(ELECTRICAL AND ELECTRONICS)

Approved by,

____
(AP DR. WONG PENG WEN)

UNIVERSITI TEKNOLOGI PETRONAS
SERI ISKANDAR, PERAK
January 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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CHONG YI CHUAN

ABSTRACT

This report describes the development of an Internet of Things (IOT) application to remotely control network instrument, Rohde & Schwarz ZVL Network Analyzer (R&S ZVL). R&S ZVL is a manually operated instrument for network parameters analysis such as High Frequency Measurement. In this study, the application created allows the user to remotely control the instrument, R&S ZVL with a host PC. Standard Commands for Programmable Instruments (SCPI) and Virtual Instrument Software Architecture (VISA) are used for the setup of instruments. Application is developed using Windows Presentation Foundation (WPF) which is a graphical development subsystem in Microsoft Visual Studio. Application is designed with customized graphical user interface (GUI) and able to identify and connect with one or more instrument. Application is expected to be able to extract Touchstone (SnP) format file which contains the data of the simulation from the instruments to the host PC. Experimental methodology and progression of works are written and explained in this report.

ACKNOWLEDGEMENTS

I would first like to thank my Final Year Project supervisor, AP Dr. Wong Peng Wen, senior lecturer of Electrical and Electronics Engineering Department at University Teknologi PETRONAS. Without his assistance and dedicated involvement in every step throughout the process, this project would have never been accomplished. I would like to thank you very much for your support and guidance in my project in spite of having a tight schedule.

I would also like to thank the FYP coordinators of Electrical and Electronics Engineering Programme. Without their passionate participation and arrangement of important dates, the flow of FYP could not have been smoothly conducted.

Finally, I would like to thank my family and friends for providing me with unfailing support and encouragement during these two semesters of Final Year Project which motivates me to strive and accomplish the researching of project and writing this paper.

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Abbreviations and Nomenclatures

DUT – Device under Test

FYP – Final Year Project

GUI – Graphical User Interface

HFM – High Frequency Measurement

IOT – Internet of Things

R&S ZVL – Rohde & Schwarz ZVL Network Analyzer

SCPI – Standard Command for Programmable Instruments

S-PARAMETERS – Scattering Parameters

VISA – Virtual Instrument Software Architecture

WCF – Windows Communication Foundation

WPF – Windows Presentation Foundation

Chapter 1

INTRODUCTION

1.1 Background

High frequency measurement is the technique used to improve the overall reliability and performance of electronic systems. In high frequency measurement, network parameters are normally measured with the aid of a network analyzer. Network analyzer is a device that captures and computes network parameters, it is commonly used to measure S-parameters for device operating in high frequency range. Rohde & Schwarz ZVL network analyzer[1] is one of the available network analyzer in market and it is widely used for test and measurement either in academic researches or industrial purposes. Moreover, there are some great utilization of high frequency techniques that involved in communication systems engineering such as magnetic cores design[2], reflector antenna analysis[3], vias designing[4], and shielding[5].

1.2 Problem statement

Existing DUT measurement devices are widely used in electronic systems design especially for microwave engineering to obtain the desired accurate network parameters. However, these measuring instruments are only available for manual operation. Manipulation of data becomes tedious to handle with the increment in the amount of data received. Furthermore, sorting data becomes another challenge when DUT measurement needs to be run on multiple network analyzer at the same time.

Regarding the problems, the proposed solution of this project will focus on how to implement an IOT based platform to automate and fasten the process for the ease of data manipulation. This research is to prove the feasibility of internetworking with multiple

DUT measurement devices and can be further implemented on any other electronic equipment that has the same characteristics with the network analyzer.

1.3 Objective

The main purpose of the project is to design an IOT application with customized user interface for DUT high frequency measurement. This IOT application will displays a logical and user-friendly graphical user interface (GUI) and at the meantime establishing a connection with multiple network analyzers that allows the interchange of data. Besides, the IOT application will be able to configure SCPI command which allows the user to remotely perform DUT measurement. Lastly, the results of measurement will be able to be exported from the network analyzer to the PC in SnP file format.

1.4 Scope of Work

The IOT application is developed using Windows Presentation Foundation (WPF), Standard Command for Programmable Instrument (SCPI) and Virtual Instrument Software Architecture (VISA). The model of the network analyzer is Rohde & Schwarz ZVL Network Analyzer. Simulation of High Frequency Measurement will be conducted remotely using a host PC. Hence, research on the implementation of IOT application will be done. Programming language used in this project is VB.NET of Microsoft Visual Studio.

Chapter 2

LITERATURE REVIEW

2.1 Internet of Things

Internet of things (IOT) is the concept of linking physical devices together while sharing information with cloud storage. It has been defined as a globalization of the information society, enabling advanced utilizes by interconnecting things based on most recent and progressing interoperable information and communication technologies. One of earliest engineering approach in development of IOT applications is the introduction of a Model-based Systems Engineering methodology for IOT applications[7]. There are also article that mentioned about the importance of IOT application and also the challenges to face with in order to improve Big Data storage systems in terms of cloud computing[8].

Similarly, a new trend has emerged in the industrial manufacturing technologies which named as Industry 4.0 or the fourth industrial revolution. The term is used to define the current innovative evolution in manufacturing technologies which generally refers to the normalization of autonomous production, internetworking of machines and cloud computing[6]. The concept of Industry 4.0 is very much alike the idea of IOT as both gave emphasis on the interchange of data in a system. "Smart system" is named for the devices or machines that are able to communicate and cooperate with each other in real time.

There are four design principles in the fourth industrial revolution. [6].

i. Interoperability, the ability of interconnecting devices, machines, sensors and people and allow them to communicate with each other via IOT application.
ii. Information transparency, the ability of information systems to create a virtual copy of the physical world by enriching digital plant models with sensor data.

iii. Technical assistance, the ability of systems to visualize information comprehensibly for making informed decisions.

iv. Decentralized decisions, the ability of cyber physical systems to make decisions on their own and to perform their tasks as autonomous as possible.

2.2 High Frequency Measurement

High Frequency Measurement is a measurement techniques used for communication device speculation such as electronic filter in signal processing. It is conducted with the aids of a network analyzer to capture and measure the network parameters of Device under Test (DUT). R&S ZVL is the model of the network analyzer that is used in this study. It is able to receive and interpret Standard Commands for Programmable Instrument (SCPI) in order to perform assigned task. SCPI command refers to the standard for syntax and commands to use in handling programmable test and measurement devices. The standard specifies a common syntax, command structure, and data formats, to be used with all instruments. A research on the characteristics and possibilities of SCPI command which involve the design of virtual oscilloscope is proposed using the technology of GPIB and SCPI on the LabVIEW platform[9].

On the other hand, PC application is needed for remote controlling the R&S ZVL. Prior to that, a software design platform or Integral Development Platform (IDE) is required for the development of the IOT application in this project. Hence, the advantages and disadvantages of several IDE are studied in order to greatly ease the process of building an IOT application. Windows Presentation Foundation (WPF)[10] is the subsystem in Microsoft Visual Studio which provides development of Windows-based application and supports C# coding language. MATLAB[11] is a platform that is widely used by developer for measurement and computing purposes application.

2.3 Related Work

Table 1: List of Related Research

No	Author	Year	Title	Method Involved	Application
1	A. Kozminski[10]	2012	WPF technology meets the challenges of operator interface design in automatic test systems	WPF developed application	Automatic Test Systems
2	S. Cannizzaro, M. C. Di Piazza, M. Luna, G.Vitale[11]	2014	PVID: An interactive Matlab application for parameter identification of complete and simplified single-diode PV models	MATLAB developed application	PVID application
3	H. Cai, B. Xu, L. Jiang, A. V. Vasilakos[8]	2016	IoT-based Big Data Storage Systems in Cloud Computing: Perspectives and Challenges	Cloud data sharing and computing	Big Data Storage System
4	B. Costa, P. F. Pires, F. C. Delicato[7]	2016	Modeling IoT Applications with SysML4IoT	System engineering involving IoT	SysML4IoT Modeling system

2.4 Critical analysis

Research has been done on IOT related studies in recent years, few methods were introduced and discussed. Among the IDE that were mentioned in the above studies, WPF and MATLAB are the most used platform in creating an IOT application. To achieve the objectives of this project, WPF is chosen as the development platform because WPF is more compatible in creating Windows-based application since it is the product of Microsoft. WPF is also able to provide a better graphical user interface than MATLAB.

Furthermore, in WPF applications, VB.NET code is only necessary to access and manage experiment data while the image rendering is managed by the User Interface XAML which significantly reduced the code length. Thus, choosing WPF will greatly reduce and ease the process of the project.

2.5 Summary

This chapter had discussed the concept of Industry 4.0 and Internet of Things. Besides, the related researches of project are discussed such as Standard Commands for Programmable Instruments (SCPI) for High Frequency Measurement. Critical analysis is carried out to select the most compatible development platform to create the application that will smoothen the flow of the project.

Chapter 3

METHODOLOGY

3.1 Project Methodology

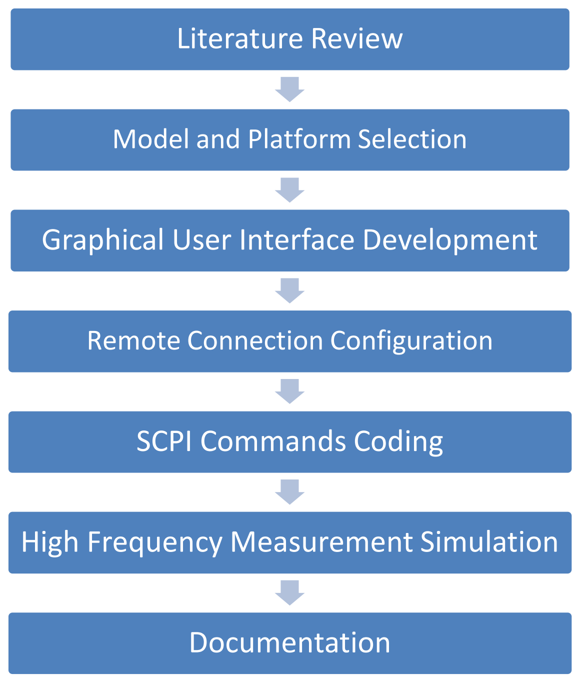

FIGURE 1: Flow of Project Work

The flow of the project work is divided into 7 phases and expected to be completed in 28 weeks. Firstly, after the approval of proposed project, researched and studies on related topic are needed to be done. Literature review of project is done by reading relevant articles and journals while also a weekly meeting with project supervisor, AP Dr. Wong Peng Wen. Proceed to the next phase, experiment model of project and development platform of application will be selected. A series of comparison will be carried out in order to have a better decision making. After the selection of model and development platform, a basic draft of graphical user interface will be created. Functional buttons and switches will be added from time to time to until the application is completely developed. Connection between R&S ZVL and host PC will then be configured and tested. The connection available in this project are: Ethernet connection and Wireless Connection.

Furthermore, SCPI commands for remote control of network instrument will be written to perform High Frequency Measurement remotely. After the completion of code, remote control of R&S ZVL using IOT application will be simulated. The process of simulation mainly focuses on three part: Calibration, Frequency Sweeping and Touchstone file export. After the proven of feasibility on the IOT application, documentation of this project will be written and discussed. Recommendation on further improvement of the project will also be included. All of the phases are shown in FIGURE 1 above.

3.2 Design Methodology

This project requires an experiment model and Integral Development Platform (IDE) to be conducted. Connection of instrument also needs to be determined in order to accomplish the Internet of Things application.

3.2.1 Model Specification

FIGURE 2: Rohde & Schwarz ZVL

The specification of Rohde & Schwarz ZVL network analyzer is listed as below:

- Frequency range: 9kHz – 13.6GHz
- Dynamic range: >115dB, typ. 123dB
- 12V DC Operation and internal battery
- LAN cable port available

3.2.2 Ethernet Connection

This project uses an IOT application to establish a connection with the network analyzer. One of the applicable connection is through Ethernet cable. It is simple to set up the connection as user only needs the information of IP address of instrument. Besides, the measured data is directly transferred within the connection without sending it to a cloud server. One of the biggest advantage of using Ethernet connection is has a lower security risk than wireless connection as it uses a physical medium. It also fulfilled the requirement of the main concept of Internet of Things which is the ability to interchange data between multiple instruments. Thus, Ethernet connection is preferred to use for testing the viability of remote controlling R&S ZVL instrument in later experiment.

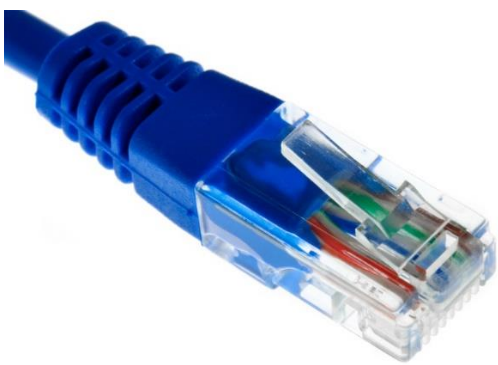

FIGURE 3: Ethernet cable

Ethernet connection is established by using guided media which is a cable to connect two computers together. However, when the number of computers increases, a network hub is needed to establish multiple links of connection. Network hub will acts as a full-duplex communication which allows both side of the machine to send and receive data from each other. In this project, SCPI commands will be sent from the PC host while SnP file is exported from the instrument.

FIGURE 4: Network Hub

3.2.3 Wireless Connection

On the other hand, the project also able to setup a wireless connection to remotely control the network analyzer. A network router will be needed to establish the wireless connection while a network USB adapter is needed for R&S ZVL as the instrument does not have an internal network port. However, there are few disadvantages of using wireless connection in this project. Firstly, this project is related to educational research and industrial simulation. Wireless connection provides a fairly weak encryption to protect transmitted data which has a high risk to encounter the exposure of classified data and malware invasion. Secondly, wireless connection is less stable than Ethernet connection because it uses a virtual medium as connection.

FIGURE 5: Network Router

Network Router Specification:

- Tenda ADSL 2+ Modem Router
- 2.4GHz Wireless N speed
- Up to 150mbps

FIGURE 6: Network Adapter

3.2.4 Integral Development Platform (IDE)

To create an application, a proper development platform is needed. After research and study on relevant designer platform, Windows Presentation Foundation (WPF) is chosen to develop the IOT application. WPF provides the compatibility to develop Windows-based application since it is a product of Microsoft Visual Studio. It also allows the user to have more options in designing graphical user interface which makes the layout of the application more attractive. The developed application will be using Standard Commands for Programmable Instruments (SCPI) for communication between PC and network instrument. The standard for remote control is described in IEEE 488.2[12]. However, SCPI cannot be sent directly from a PC to an instrument, host PC is required to install Virtual Instrument Software Architecture (VISA) libraries which acts as a converter to convert SCPI commands into machine language so that the instrument can reads. In addition, the developed application uses TCP/IP protocol with Ethernet connection.

3.3 Gantt chart

TABLE 2: Timelines for FYP I

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Literature Review															
2	Selection of Model and Platform															
3	Design basic GUI layout															
4	Connection Configuration															
5	Develop HFM SCPI command															
6	Submission of Dissertation (soft bound)															
7	Proposal Defense															
8	Extended Proposal															
9	Interim Report															

TABLE 3: Timelines for FYP II

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	GUI Update															
2	ZVL Calibration															
3	ZVL Frequency Sweep															
4	ZVL High Frequency Measurement															
5	Progress Report															
6	Pre-SEDEX															
7	Submission of Draft Final Report															
8	Submission of Dissertation (softbound)															
9	Submission of Technical Paper															
10	Viva															
11	Submission of Project Dissertation															

3.4 Project Key Milestones

i. Literature Review

Operating procedures of R&S ZVL and theory on High Frequency Measurement are further researched. Meantime, Integral Development Platforms for IOT application are also studied and compared.

ii. Developing graphical user interface (GUI)

Basic user interface of IOT application is developed. Functional buttons and selection input are added. SCPI commands for network instrument R&S ZVL are written for remote connection with host PC.

iii. High Frequency Measurement Remote Simulation

Remote calibration of R&S ZVL ports. High Frequency Measurement is simulated remotely from the host PC. Results are captured in touchstone file format and store in selected PC directories.

Chapter 4

RESULTS AND DISCUSSION

4.1 Graphical User Interface (GUI)

Using Windows Presentation Foundation and VB.NET language, basic GUI of IOT application is developed. In FIGURE 7, the layout of the application is adjusted and the position of buttons and image are set pixels by pixels.

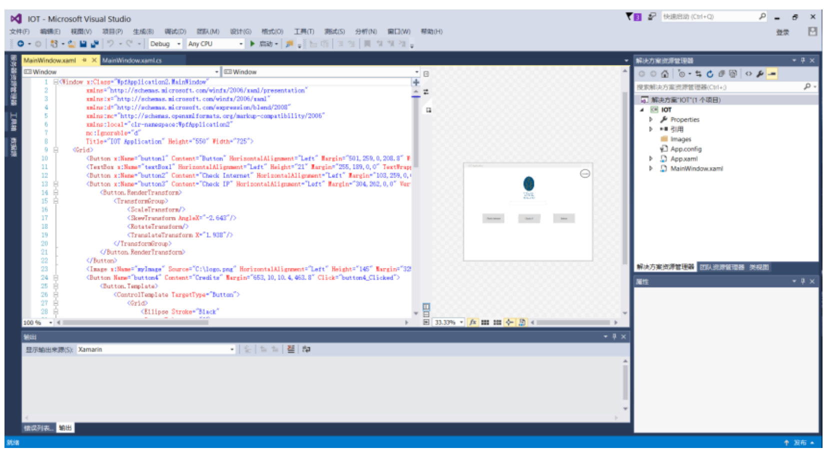

FIGURE 7: Layout Adjustment

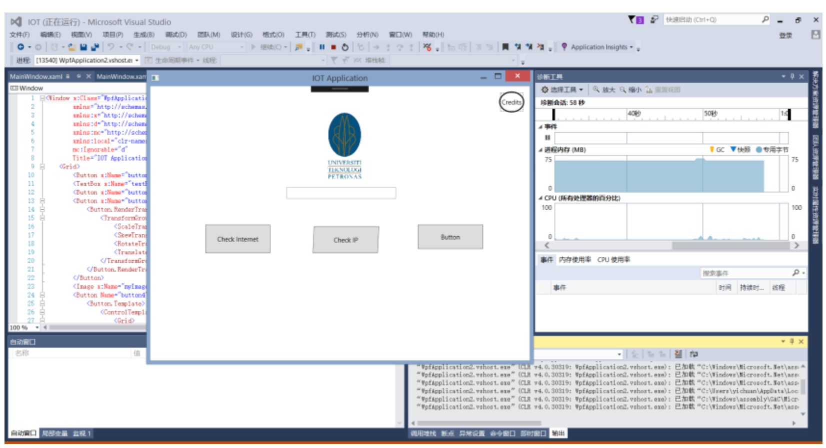

FIGURE 8: Simulating Application

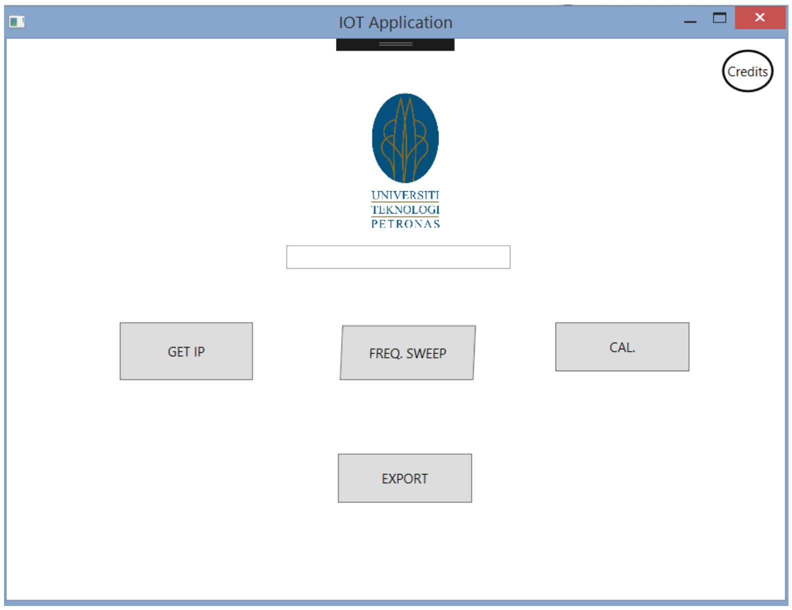

FIGURE 9: Full Screen Layout

4.2 Functional Buttons

There are total 5 buttons in the User Interface of the application.

i. GET IP

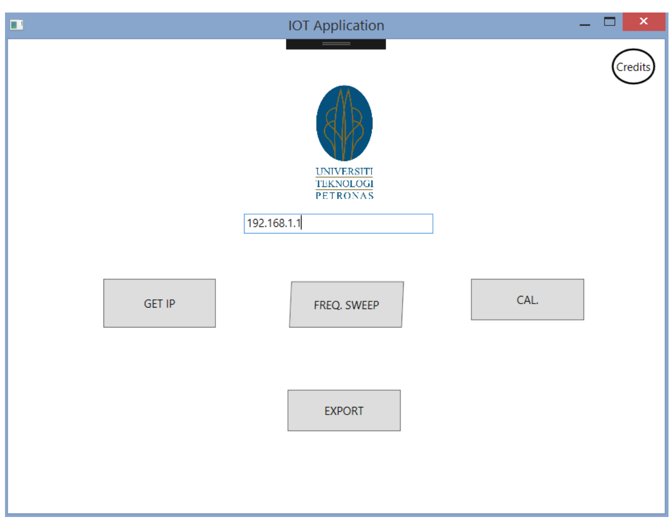

FIGURE 10: Obtained Instrument IP

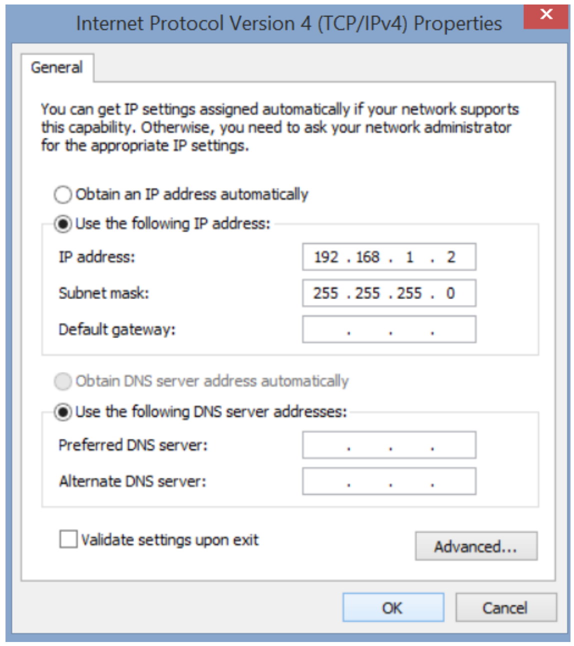

FIGURE 10: IP Configuration

GET IP will obtain IP address of the connected instrument. Then, user will have to configure the host PC IP address as shown in FIGURE 10 in order to match the instrument IP address.

ii. CAL.

To calibrate the instrument, a calibration kit is needed. User has to connect the calibration kit with the respective PORTs of Open, Short, Match and Thru connection.

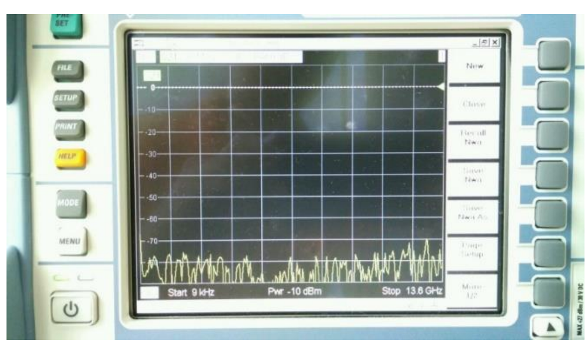

FIGURE 11: Before Calibration

FIGURE 12: Short Connection

FIGURE 13: Open Connection

FIGURE 14: Thru Connection

FIGURE 15: Match Connection

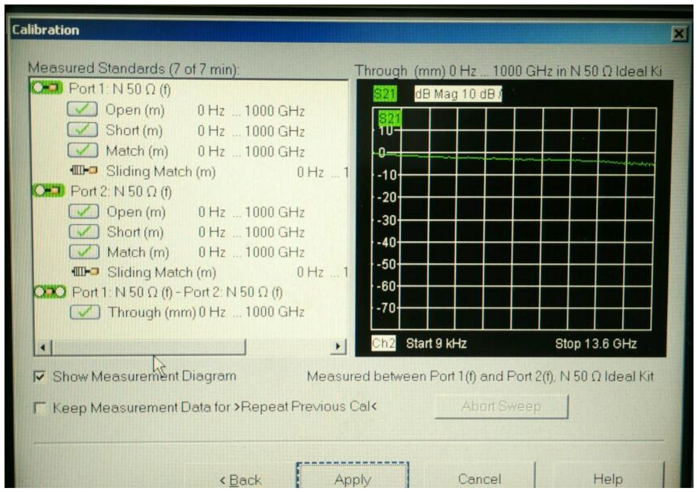

FIGURE 16: Complete Calibration

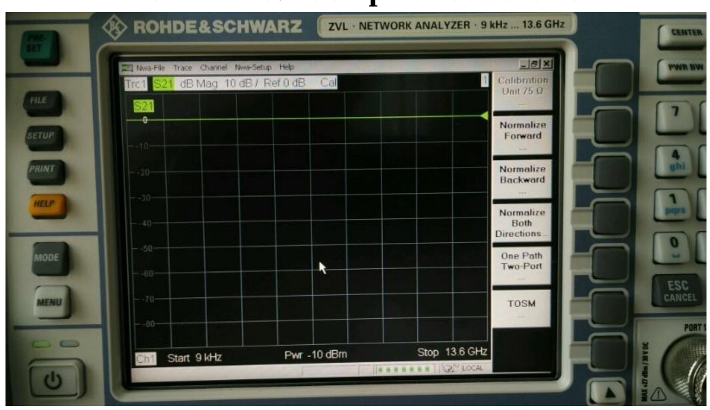

FIGURE 17: Calibrated Instrument

As shown in FIGURE 17, the instrument gives a perfect straight line at 0 dB after the calibration is done. In other word, the further simulation of this instrument will not effected by zero errors.

iii. FREQ. SWEEP

FIGURE 18: Frequency Sweep

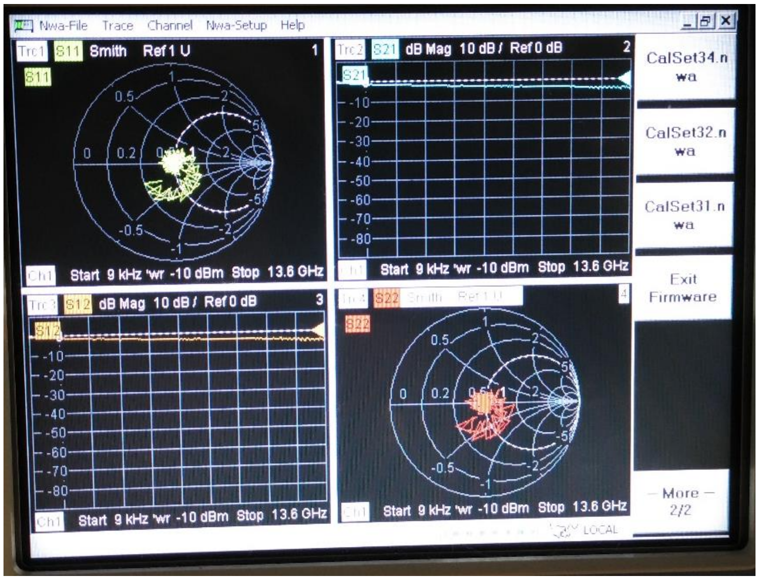

FIGURE 19: 4 Traces 4 Diagrams

iv. EXPORT

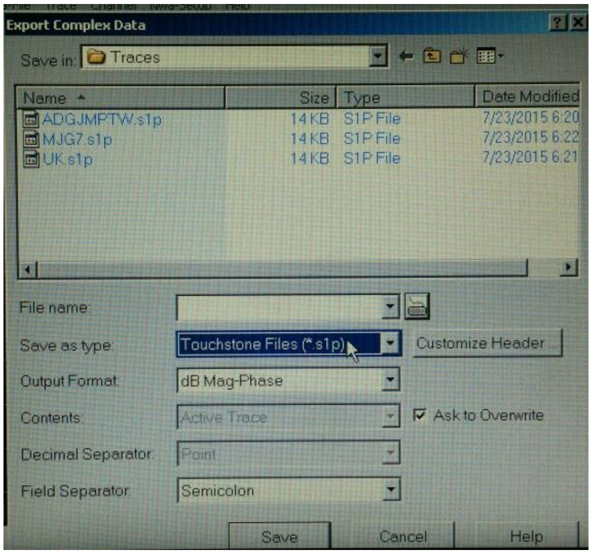

FIGURE 20: *s1p File

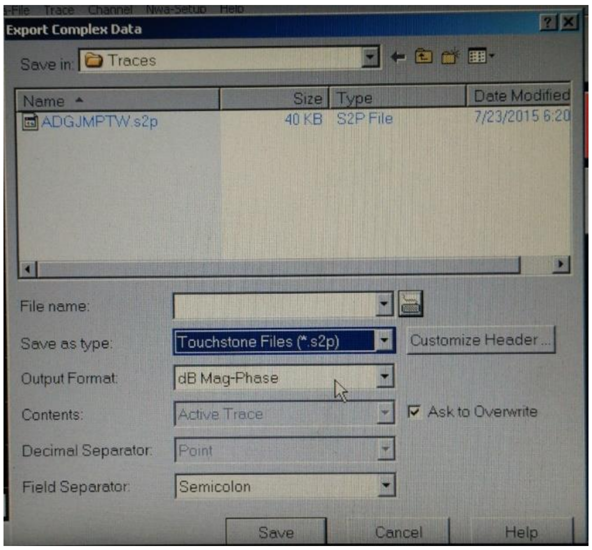

FIGURE 21: *s2p File

v. CREDITS

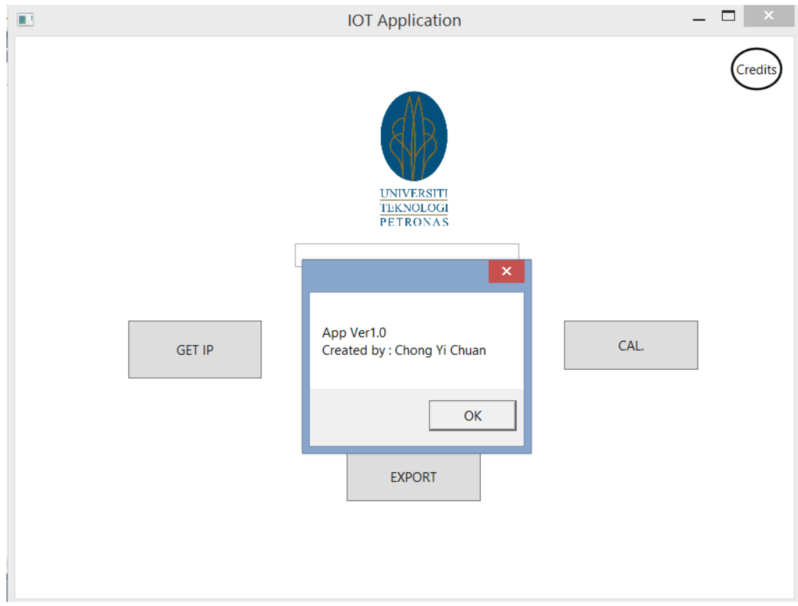

FIGURE 22: Credits Information

CREDITS button is pressed to show the current version of the application. Information such as creator of application is also displayed. The button will be updated from time to time to display the latest version of application. As further improvement of the application is done, more information is suggested to be displayed in the CREDITS section.

4.3 Discussion

As conclusion of the results, High Frequency Measurement is simulated with the IOT application using Ethernet connection. The connection of host PC and R&S ZVL is shown in FIGURE 23. Calibration of instrument has been done. Frequency sweep in the range of 1GHz is simulated. The results are stored in s1p and s2p format then exported to the host PC.

FIGURE 23: Physical Connection

Chapter 5

CONCLUSION AND RECOMMENDATION

In conclusion, the main objective of this project is achieved which is to develop an IOT application for DUT high frequency measurement. The IOT application provides a logical graphical user interface (GUI) which is user-friendly to new learner of instrument. Besides, the IOT application sends SCPI command to R&S ZVL analyzer from the host PC and exports the Touchstone file (*s2p format) from it. Data is being interexchange between the connection of PC and instrument which forms a data sharing link. The concept of IOT application in DUT High Frequency Measurement is proven.

Due to some limitation in this project: limited budget and single model instrument available; some features were not be able to experiment throughout the progression. However, future improvement of this project is viable. For example, wireless network modem can be used to replace the existing Ethernet connection if more than one model instrument are available for testing. Other than that, new functional buttons can be added to the application to allow the IOT application of other network measurement techniques to be carried out remotely.

With that, it concludes the project “IOT Application in DUT High Frequency Measurement”. This project aims to advance the implementation of IOT devices, mainly for educational and industrial purposes. With further advancement of communication technologies, IOT devices would make a noticeable impact which all devices are interlinking for simplicity and convenience.

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APPENDICES

MainWindow.xaml code

```
Window x:Class="MainWindow"
        xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
        xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
        xmlns:d="http://schemas.microsoft.com/expression/blend/2008"
        xmlns:mc="http://schemas.openxmlformats.org/markup-compatibility/2006"
        xmlns:local="clr-namespace:WpfApplication5"
        mc:Ignorable="d"
        Title="MainWindow" Height="350" Width="525">
    <Grid>
        <Button x:Name="button" Content="GET IP" HorizontalAlignment="Left"
VerticalAlignment="Top" Width="75" Margin="377,240,0,0"/>
        <Button x:Name="button1" Content="FREQ. SWEEP" HorizontalAlignment="Left"
VerticalAlignment="Top" Width="75" Margin="264,240,0,0"/>
        <Button x:Name="button2" Content="CAL." HorizontalAlignment="Left" VerticalAlignment="Top"
Width="75" Margin="150,240,0,0"/>
        <Button x:Name="button3" Content="EXPORT" HorizontalAlignment="Left"
VerticalAlignment="Top" Width="75" Margin="57,182,0,0"/>
        <Button x:Name="button4" Content="CREDITS" HorizontalAlignment="Left"
VerticalAlignment="Top" Width="75" Margin="57,206,0,0"/>

    </Grid>
</Window>
```

MainWindow.xaml.vb code

```
Class MainWindow
    Private Sub button_Click(ByVal sender As System.Object, ByVal e As _
    System.EventArgs) Handles button.Click
        Dim ioMgr As Ivi.Visa.Interop.ResourceManager
        Dim instrument As Ivi.Visa.Interop.FormattedIO488
        Dim idn As String
        ioMgr = New Ivi.Visa.Interop.ResourceManager
        instrument = New Ivi.Visa.Interop.FormattedIO488
        ' use instrument specific address for Open() parameter - i.e. GPIB0::22
        instrument.IO = ioMgr.Open("TCPIP0::192.168.1.1::INSTR")
        instrument.WriteString("*RST")
    End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As _
    System.EventArgs) Handles button1.Click
        Dim ioMgr As Ivi.Visa.Interop.ResourceManager
        Dim instrument As Ivi.Visa.Interop.FormattedIO488
        Dim idn As String
        ioMgr = New Ivi.Visa.Interop.ResourceManager
        instrument = New Ivi.Visa.Interop.FormattedIO488
        instrument.IO = ioMgr.Open("TCPIP0::192.168.1.1::INSTR")
        instrument.WriteString("*RST
       ")
    End Sub
    Private Sub button2_Click(ByVal sender As System.Object, ByVal e As _
    System.EventArgs) Handles button1.Click
        Dim ioMgr As Ivi.Visa.Interop.ResourceManager
        Dim instrument As Ivi.Visa.Interop.FormattedIO488
        Dim idn As String
        ioMgr = New Ivi.Visa.Interop.ResourceManager
        instrument = New Ivi.Visa.Interop.FormattedIO488
        instrument.IO = ioMgr.Open("TCPIP0::192.168.1.1::INSTR")
        instrument.WriteString("*RST
        :SENSE:CORRECTION:CKIT:N50:SELECT  'N 50 Ohm Ideal Kit'
        :SENSE1:CORRECTION:COLLECT:CONNECTION1 N50FEMALE
        :SENSE1:CORRECTION:COLLECT:CONNECTION2 N50FEMALE
        :SENSe:CORRection:COLLect:ACQuire:RSAVe:DEFault OFF
        :SENSe1:CORRection:COLLect:METHod:DEFine     'Test SFK TOSM 12', TOSM, 1, 2
        :SENSe1:CORRection:COLLect:ACQuire:SELected  THROUGH, 1, 2
        :SENSe1:CORRection:COLLect:ACQuire:SELected  OPEN,  1
        :SENSe1:CORRection:COLLect:ACQuire:SELected  SHORT, 1
        :SENSe1:CORRection:COLLect:ACQuire:SELected  MATCH, 1
        :SENSe1:CORRection:COLLect:ACQuire:SELected  OPEN,  2
        :SENSe1:CORRection:COLLect:ACQuire:SELected  SHORT, 2
```

```
/
        :SENSe1:CORRection:COLLect:ACQuire:SELected  MATCH, 2
        :SENSe1:CORRection:COLLect:SAVE:SELected
        :MMEMORY:STORE:CORRection 1, 'OSM1 TOSM12.cal'
        :MMEMORY:LOAD:CORRection  1, 'OSM1 TOSM12.cal'")
    End Sub
        Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As _
    System.EventArgs) Handles button1.Click
        Dim ioMgr As Ivi.Visa.Interop.ResourceManager
        Dim instrument As Ivi.Visa.Interop.FormattedIO488
        Dim idn As String
        ioMgr = New Ivi.Visa.Interop.ResourceManager
        instrument = New Ivi.Visa.Interop.FormattedIO488
        instrument.IO = ioMgr.Open("TCPIP0::192.168.1.1::INSTR")
        instrument.WriteString("*RST
        CALCulate1:PARameter:SDEFine 'Trc2', 'S21'
        CALCulate1:FORMat PHASe
        SENSe1:BANDwidth:RESolution 10
        DISPlay:WINDow1:TRACe2:FEED 'Trc2'
        SYSTem:DISPlay:UPDate ONCE")
    End Sub
    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e As _
    System.EventArgs) Handles button1.Click
        Dim ioMgr As Ivi.Visa.Interop.ResourceManager
        Dim instrument As Ivi.Visa.Interop.FormattedIO488
        Dim idn As String
        ioMgr = New Ivi.Visa.Interop.ResourceManager
        instrument = New Ivi.Visa.Interop.FormattedIO488
        instrument.IO = ioMgr.Open("TCPIP0::192.168.1.1::INSTR")
        instrument.WriteString("*RST
        DISplay Credits")
    End Sub


End Class
```