# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# OPTIMIZATION PROCESS BY USING DESIGN OF EXPERIMENT (DOE) FOR FIBER OPTIC DISTANCE SENSOR

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Telecommunication) (Hons.)

By


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**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA**

TAJUK: **OPTIMIZATION PROCESS BY USING DESIGN OF EXPERIMENTS (DOE) FOR FIBER OPTIC DISTANCE SENSOR**

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# APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Telecommunication) (Hons.). The members of the supervisory committee are as follow:

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(Principal Supervisor)

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(Co-Supervisor)

# ABSTRACT

This project proposes to use design of experiment for optimization of fiber optic distance sensor. The accuracy of normal sensor produces is affected by critical experimental parameters. The effects of these key variables on the fiber optic distance sensor efficiency were investigated. The low power output on the normal sensor was determined in many industrial area, as responses to that problem, design of experiment (factorial design) is the way that will assist the industrial to get the better output result or more accuracy on their sensor. The accuracy was checked using one standard reference material or variable which are; type of cable used, type of light source used, and distance of the sensor to the target and permittivity for an experiment. Factorial design $2^4$ will applied to determine the significant factors that affect the output power. By using DOE tool, this experiment will be carried out systematically, effectively and efficiently.

# ABSTRAK

Projek ini dicadangkan untuk menggunakan kaedah reka bentuk pengoptimum eksperimen gentian optik pengesan jarak. Kebiasaannya, ketepatan pengesan biasa yang dihasilkan dipengaruhi oleh pembolehubah eksperimen yang melampau. Kesan pembolehubah utama dalam gentian optik kecekapan pengesan jarak akan dikaji. Keluaran kuasa yang rendah pada pengesan jarak biasa telah banyak digunakan di kawasan perindustrian, sebagai penyelesaian kepada masalah itu, reka bentuk eksperimen (reka bentuk faktorial) adalah cara yang terbaik untuk membantu industri mendapatkan hasil keluaran yang lebih baik atau lebih tepat pada pengesan jarak mereka. Ketepatan diperiksa menggunakan satu bahan rujukan biasa atau pembolehubah iaitu; jenis kabel yang digunakan, jenis sumber cahaya yang digunakan, dan jarak pengesan kepada objek dan ketelusan untuk percubaan. Reka bentuk faktorial $2^4$ akan digunakan untuk menentukan faktor-faktor penting yang memberi kesan kepada kuasa keluaran. Dengan menggunakan alat DOE, eksperimen ini akan dilaksanakan secara sistematik, cekap dan berkesan.

# DEDICATIONS

*To my beloved parents*

Mr Aminuddin bin Ahmad

Mrs Dayang Siti Aini binti Abdul Salam

*To my supportive wife and sibling*

Mrs Azwani binti Ahmad Adzhar

Mrs Nurul Azniezah binti Aminuddin & Husband

*To my supervisor*

Mrs Rahaini binti Mohd Said

*and my treasured friends*

BETT

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| DOE | = | Design of Experiment |
| FODS | = | Fiber Optic Distance Sensor |
| LED | = | Light Emitting Diode |
| LD | = | Laser Diode |
| DX9 | = | Design Expert 9 |
| OSA | = | Optical Spectrum Analyzer |
| FFD | = | Full Factorial Design |
| ANOVA | = | Analysis of Variance |
| PI | = | Prediction Interval |
| SM | = | Single Mode |
| MM | = | Multimode |
| cm | = | Centimeter |
| µm | = | Micrometer |
| mm | = | Millimeter |

# CHAPTER 1

# INTRODUCTION

## 1.0 Introduction

This chapter will give a brief explanation about this project, based on the project title 'Optimization Process by using Design of Experiment (DOE) for Fiber Optic Distance Sensor, have two topics will be discuss in this project which are about the Design of Experiment and Fiber Optic Distance Sensor. Besides that, it also cover the background, problem statement, objectives, scope project and summary of this chapter.

## 1.1 Background of the Study

From the title of the project, Optimization Process by using Design of Experiment (DOE) for Fiber Optic Distance Sensor, this project will be run the experiment by using fiber optic distance sensor with four different parameter to compare the output. The application of fiber optic distance sensor is to detect an object or target from the laser. Firstly, distance sensor using fiber optic will be develop for the experimentation. Currently, the fiber optic distance sensor still not perform by using design of experiment, so the accuracy of distance sensor still not in optimize performance, need improvement to implement in industrial area as a new device with optimize output power. Therefore, to optimize the output power the technique Design of Experiment will be applied. The experimentation will run sixteen times by changing the parameter one by one. Then, Design Expert 9 Software will simulate and perform the results collected. Design of experiment is one of a powerful method to optimize a system performance. To start the experimental design, need to start with the objectives of an experiment and identifying the factor that involves for the study.

## 1.2 Design of Experiment (DOE)

Design of Experiment (DOE) is a method with a systematic process to define or determine the relationship that affect a system or process and the output of the process. To find the cause and effect of a problem, DOE can be used. To manage process inputs, the information about the process is needed in order to optimize the output. The arrangement of various conditions or situations to which experiment subject will be exposed is the main concerns of Design of Experiment (DOE). An analysis of variance is performed on the data gathered and observation of the responses of the subjects is made. (Wayne Lee, 1975).

Design of experiment is used to manipulate and determine their effect on a desired output or responses and can allow for multiple input factors. DOE can identify the most important interaction that may be missed when experimenting with one factor at a time by manipulating multiple inputs at the same time. All possible combinations can be investigated by using full factorial or only a portion of the possible combinations by using fractional factorial.

To improve product quality and reliability is to integrate them in the design and manufacturing process design of experiment (DOE) is a one of effective ways. A useful tool that can be integrated into the early stages of the development cycle is design of experiment (DOE) because by many industries including automotive, semiconductor, medical devices, chemical product and many others it has been successfully adopted DOE. But until now still not be applied in fiber optic experiments (Wayne Lee, 1975).

DOE methods are suitable used in the process of development and troubleshooting to improve or optimize the performance. Based on the research, experimental design abilities to determine many factors, for example, determine which input variables are the best on the output response and determine where to set the influential input variables so that output response is near the nominal requirement. (Montgomery, 2005)

## 1.3 Type of Design of Experiment (DOE)

There are many types of DOE, for example, full factorial design, fractional factorial design, screening design and mixture design.

### 1.3.1 Full Factorial Design

A full factorial design is an example of DOE, which is the design that contains all possible combinations of a set of variable or factors. Both continuous factors and categorical factors with up to nine levels was supported by full factorial design. An experimental run at every combination of the factor levels can perform by full factorial design. The numbers of levels of the factors are the sample size of the product. For example, 2 x 3 x 4 = 24 runs are a factorial experiment with a two-level factor, a three-level factor, and a four-level factor. A sample size that is a power of two specifically 2f where f is the number of factors is also factorial design with only two-level factors. The factorial design points are at the vertices of a cube is a design of full factorial with three factors. Full factorial designs are the most conservative of all design types. The difference in response between the levels of one factor is not the same at all levels of the other factors in some experiments. There is an interaction between the factors when this has happened. (G.O. Verran, 2008)

### 1.3.2 Fractional Factorial Design

An adequately chosen fraction of the treatment combinations required for the complete factorial experiment is selected to be run is a factorial experiment. For fractional factorial design, need to add a good number of center point runs and need to quickly run up a very large resource requirement for runs with only a modest number of factors. Fractional factorial design is used to solve this problem if the experiment can find a very large resource requirement to run, so fractional factorial design will select only a fraction of the runs specified by the full factorial design. To select the variable which runs make and which to leave out is the main topic of interest here. Normally, from the runs called full factorial will be selected by picking a fraction such as ½, ¼ and etc. To ensure an appropriate choice of runs need to use several of strategies and do some more research. (ASQC, 1983)

### 1.3.3 Screening Design

This design will examine the many factor to see which have the greatest effect on the result of a process. Screening design will use or require the fewer experimental runs compared to other design method. So, for this design will be cheaper in term of cost running the experiments, but this design also attractive and efficient way to begin improving a process. The critical assumption of the effect sparsely will affect the efficiency of the screening design. As the theory of screening design, this design will reduce the number of runs at the experiment because they will restrict the factor to two or three levels. If the number of runs is too much, better do the experiment by using full factorial design or fractional factorial design. Usually, in a screening design, each factor is set at two levels to economize on the number of runs needed and response measurement is taken for only a fraction or the possible combination of levels. Furthermore, the separate effects of the three factors can still assess by doing half of these eight combinations. Screening design can approach reduces the number of runs from 24 runs of the experiment to 4 runs of the experiment, this is the specialty of this design. (J.S Hunter, 2005)

### 1.3.4 Mixture Experiment Design

Mixture Design is a design can supports experiment with factors that are ingredients in the mixture. The properties of a mixture are almost always a function of the relative proportions of the ingredients rather than their absolute amounts. A factor value is its proportion in the mixture, which falls between zero and one of the experiments with mixtures. The sum of the proportions in any mixture recipe is one or 100%. Designs for mixture experiments are fundamentally different from those for screening. With mixtures, it is impossible to vary one factor independently of all the others. When you change the proportion of one ingredient, the proportion of one or more other ingredients must also change to compensate. This simple fact has a profound effect on every aspect of experimentation with mixtures: the factor space, the design properties, and the interpretation of the results. Because the proportion sum to one, mixture designs have an interesting geometry. The feasible region for a mixture takes the form of a simplex (Simon M.J., 1997).

## 1.4 Problem Statement

Nowadays, fiber optic distance sensor perform normal output or standard performance, not the optimize output and high performance. Some manufacturing company using distance sensor with standard distance sensor without using fiber optic distance sensor. By using fiber optic distance sensor as sophisticated devices will perform the better results and the output are more consistent and stable. When distance sensor is analyze by using Design of Experiment (DOE) it can define the optimum output power.

## 1.5 Objectives of Project

Based on the title "Optimization Process by using Design of Experiment (DOE) for Fiber Optic Distance Sensor (FODS)", below is the objectives of the project to be achieved at the end of this project.

i. To apply Design of Experiment (DOE) for optimization of fiber optic distance sensors.
ii. To identify the parameter that will optimize the output power by using Design of Experiment (DOE).
iii. To develop fiber optic distance sensor.

## 1.6 Project Scope / Work Scope

This project will develop a Fiber Optic Distance Sensor to apply in the industrial or manufacturing area. This project is more focus on Design of Experiment (DOE), because DOE approach will be employed assist to optimize the output result. Fiber optic distance sensor can be applied in the manufacturing industry, public area and on vehicles. This sensor with high accuracy will detect the object with high accuracy and high stability without have interference from the environment and temperature.

# CHAPTER 2

## LITERATURE REVIEW

### 2.0 Literature Review

This chapter reviews some references from previous projects and information of the projects. Propose of this chapter is to identify and analyze all the intellectual information and necessity in the process of build fiber optic distance sensor by using design of experiment.

### 2.1 Factorial Design usage in Optimization

Factorial design consists of full factorial design and fractional factorial design. A full factorial DOE is a planned set of tests on the response variables with one or more factors with all combinations of levels. DOE is a design method can use for process development or process troubleshooting to improve the process performance and get the optimum output. In this project, will applied the factorial design to improve the manufacturability of the product, improve the process in the industrial, enhanced field performance and reliability, lower product cost and shorter product development time. So, to start this experiment must follow the step or flow chart of DOE. Figure 2.1 below show the flow chart of design of experiment (DOE).

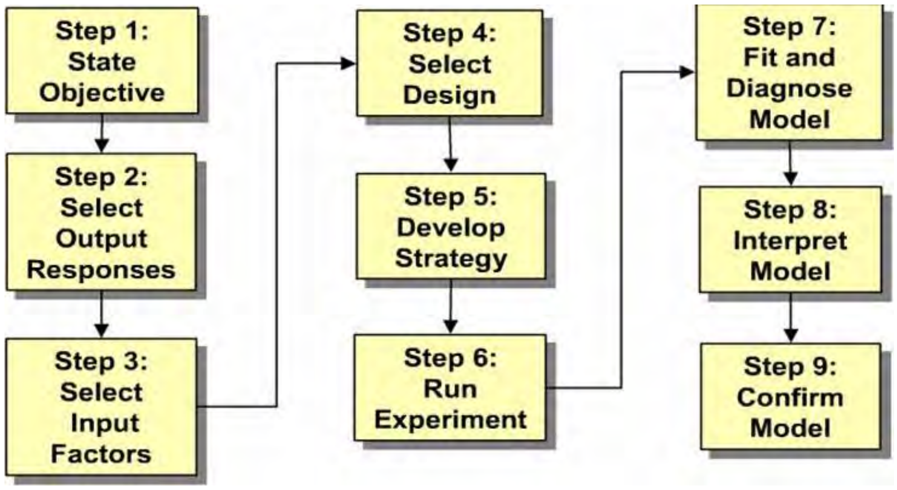


**Figure 2.1: Flow Chart of Design of Experiment**

### 2.1.1 2k Factorial Design

Factorial design is widely used in the experiments involving several factors where it is necessary to study the intersection of the factors on a response. The most important of these cases is that of k factors, each at only two levels. These levels may be quantitative, such as two value of temperature, pressure or time, or may be qualitative such as two machines, two operators, and the high and low level of a factor. A complete replicate of such a design requires 2 x 2 x …. x 2 = $2^k$ observations and is called a $2^k$ factorial design. In these designs we will refer to the levels as high and low, +1 and -1, to denote the high and the low level of each factor. (S.R. Schmidt, 1997)

Since there are two levels of each of the two factors, A and B, and each factor have two levels, low and high which is 2k equals four. The "-" and "+" denote the low and high levels of a factor, respectively while the low and high are arbitrary terms. Geometrically, the four runs from the corners of a square and the factors can be quantitative or qualitative, although their treatment in the final model will be different. (S.R. Schmidt, 1997)