UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## Faculty of Manufacturing Engineering

# ANALYSIS OF PLASTIC MATERIAL MOISTURE ABSORPTION AND DISSIPATION CHARACTERISTIC FOR CRYSTAL ROD HOLDER DESIGN OPTIMIZATION

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**Master of Manufacturing Engineering**
**(Manufacturing System Engineering)**

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# ANALYSIS OF PLASTIC MATERIAL MOISTURE ABSORPTION AND DISSIPATION CHARACTERISTIC FOR CRYSTAL ROD HOLDER DESIGN OPTIMIZATION

LEE PEY JIUAN

**A thesis submitted**
**in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Manufacturing System Engineering)**

**Faculty of Manufacturing Engineering**

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**DEDICATION**

To my beloved family

# ABSTRACT

Crystal rod holders (CRH) are mounted in tunable filter microcircuits assembled inside the Signal or Spectrum Analyzer. Performance repeatability is an important criteria for the Spectrum Analyzer. CRH can be in varieties of design and materials to hold the different tunable filter microcircuit frequency range. The problem is the crystal rod holder having moisture absorption and latent failure over time. The objective of this project is to study the moisture absorption and dissipations rate for different grade of plastic materials in the production environment, targeting to understand the current plastic characteristic and to identify alternative plastic materials for product functional optimization. Experiments were performed to compare the plastic materials under study with the current material on the moisture absorption and dissipation rate. The experiments were performed by utilizing the available resources, tools and equipment in the production floor. Samples were prepared to evaluate the moisture absorption and dissipations rate. At the end of the project, equations were generated to estimate moisture absorption rate and drying temperature versus time to eliminate moisture after exposure to the atmosphere over time. Besides, the testing criteria of the internal standards of MILSTD 883 and MILSTD 210D qualification were applied in this experiment study as well.

## ABSTRAK

*Pemegang rod krystal (CRH) dipasang dalam penapis laras litar mikro dalam peralatan ukur Spektum. Ulangan prestasi keputusan adalah ciri yang penting bagi peralatan ukur Spekrum. CRH boleh didapati dalam beberapa jenis reka bentuk dan bahan untuk memegang penapis laras litar mikro yang berlain julat frekuensi. Masalahnya ialah CRH isu penyerapan kelembapan dari sekeliling udara dan mengalami kegagalan lewatan. Objektif projeck ini adalah mempelajari kadar penyerapan kelembapan dan kadar pengeringan bagi beberapa gred bahan plastik yang berlainan di sekeliling pengeluaran, untuk memahami ciri-ciri plastic semasa, dan untuk memilih bahan plastik yang baru bagi meningkatkan fungsi produk. Eksperimen ini telah dijalankan untuk membanding kadar penyerapan and pengasingan kelembapan bahan plastik dalam analisa dengan bahan plastik semasa. Eksperiment telah dijalankan dengan mengunakan sumber dan peralatan yang sedia ada di tempat pengeluaran. Sampel telah disediakan untuk menilai kadar penyerapan and pengasingan kelembapan. Pada akhir projek ini, persamaan telah dijanakan untuk menentukan kadar kelembapan dan suhu pengeringan dengan masa untuk mengasingkan kelembapan selepas pendedahan ke sekeliling sepanjang masa. Selain daripada ujian kaedah pengukuran dan system kelayakan di Keysight Technologies, kaedah antrabangsa telah digunakan dalam penguji kajian ini seperti MILSTD 883 and MILSTD 210D.*

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| Hz | - | Hertz |
| GHz | - | Giga Hertz |
| K | - | Kelvin |
| mm | - | millimeter |
| Q | - | Quality |
| °C | - | Degree Celsius |
| mg | - | milligrams |
| g | - | gram |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Signal or Spectrum Analyzer (SA) is a test equipment that used to measure the magnitude of an unknown input signals versus the frequency within the available frequency range of the measurement instruments. This measurement is done on products signals that operate at frequency 3 Hz and above until 50GHz that used in Radio Frequency (RF) field in the market. A SA is available with many varieties of options based on the type of filters and the frequency range in the industries. SA available in the market is capable of real time measurement and signal analyzing. Example of Spectrum Analyzer on Figure 1.1

Figure 1.1 Schematic representation of the Spectrum Analyzer. Love (2013)

Accuracy of the SA is an important part of characterizing RF signal or microwave circuits and devices characteristic. SA functionality repeatability rely on the accuracy of the tunable filter microcircuit performance. Tunable filter microcircuits capable of filtering frequency between 3.5 GHz to 50 GHz. Example of tunable filter microcircuit is in Figure

1.2. The repeatability of the tunable filter microcircuit consists of mathematically derives the systematic error model.

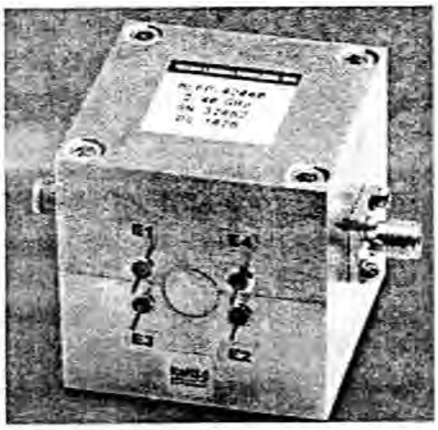

Figure 1.2 Tunable Filter Microcircuit. Microwave Product Digest (2016)

The error of the model will be significant when user perform calibration and absolute measurement instead of relative measurement comparison. This is because all the bandwidth has moved and not able to establish a fixed reference plane of zero phase shift and return to the original phase. The error of not able to return to the original phase is known as degradation. The error is often corrected by adjustment during calibration cycles according to standards. Recalibration method is an example of only one of the many possible remedy available.

All the tunable filter microcircuits were designed with its specific purpose. Certain applications require acceptable performance across a range of frequencies in conditions ranging from controlled laboratory settings such as metrology or production testing until extremely harsh outdoor environments that need extra protection from wind, rain, ice, humidity and extreme temperatures. In many cases, the tunable filter microcircuits durability is an important issue for both the space consideration due to the size diameter of the components inside the microcircuits which must be accommodated and fixed within the SA instruments that capable to sustained and survive at the elevated temperature, random vibration during transportation and shock impacts.

Most of the time, the tunable filter microcircuits are used quite successfully under condition for which it is not designed for use at certain frequency range. It is recommended that to only use the tunable filter microcircuits with proven application for their designed in any usage. Somehow, if the tunable filter microcircuit type had been wrongly chosen then it will start to generate problem with the quality of the measurement instruments. This has been frequently happened in electronic equipment or components. For example, a tunable filter microcircuit of 3.5 GHz doesn't suitable to operate below 3.5 GHz but a methodology grade of the tunable filter microcircuit with specialize crystal designed can operate below 3.5 GHz up to 3.4 GHz.

Therefore, this project proposes to optimize the tunable filter microcircuit performance repeatability by study the moisture absorption and dissipation rate for different grade of plastic materials in the production environment, targeting to understand the current plastic characteristic and use the results to identify alternative plastic materials for product functional optimization to meet industrial document standards and international standards such testing in the humidity chamber according to the military MILSTD 883C Methods 2002.3, MILSTD 210D environmental test methods requirements.

## 1.2 Background of Study

Tunable filter microcircuit designed and manufactured as a bandpass filter in SA to filtered an unknown incoming signal. The major specifications are the frequency range that the tunable filter microcircuit able to reject and only show the desired frequency. Each of the tunable filter microcircuits has its unique parameters as well as its own cautions and techniques for making reliable frequency filtering.

Tunable filter microcircuit is an assembly combinations of various components, such as crystal spheres, crystal rod holder (CRH), semi-rings, springs, housing, magnet and so on.

One of the Tunable filter microcircuits components named CRH will be the focus of the study. The CRH is made of plastic materials. CRH is molded by plastic injection molding process, next it then assembled with components to hold the crystal sphere.

## 1.3 Problem Statement

When a bad CRH or any deformation on the assembly connection path, there's a percentage of signal movement or degradation over time (Keysight, 2006). The incoming signal waves will not be able to filter and reject based on the lock down magnetic field causing the whole bandwidth to move. The signal wave will bounce off from the initial reference line when perform absolute measurement to calibrate based on the correct initial data. For example: when incoming signal is being coupled at the predefined magnetic field, with the incorrect position of the crystal sphere, the outgoing data will show a variety of odd results. If the same signal is being input after a period of time, assumed after a month, the result will not be repeated when compare to the data measured a month ago.

CRH is very important in the tunable filter microcircuit as minor deformation will result in dislocation of the crystal sphere, especially during high frequency of 50 GHz. Due to the nature of the plastic materials absorb moisture and deformed over time which cause the crystal to distorted and result the crystal no longer at the optimal position. Moreover, CRH assembly expansion did not show a disoriented trend but the disorientation is in all directions.

In the ideal case, all the components do not degrade overtime. Software simulation also cannot estimate the specific degradation overtime. But in the real case, the tunable filter microcircuit has a loss. When the CRH absorb moisture in the tunable filter microcircuit, it has potential to damage other components as well. Thus it leads to a result of high reject rate, cost and time. It is difficult to determine the CRH condition if good or bad by visual inspection nor measurement, as the CRH defect only happen over time after exposure to the environment or heat. Therefore this project has been carried out to understand the characteristic of the plastic moisture absorption and dissipation characteristic in order for actions to be taken when performing corrective action.

## 1.4 Objective

The objectives of this research are:

(i) To investigate the moisture absorption rate for the different grade of plastic materials in the production environment,

(ii) To Investigate the moisture dissipation rate for different grade of plastic materials in the production environment, and

(iii) To identify the alternative plastic for product functional optimization test.

## 1.5 Scope

The scope of this research is to study the current CRH and new plastic materials characteristic in terms of moisture absorption from atmosphere, moisture dissipation by utilizing the current resources available in the production and office environment. The study involves material selection, experimental setup methodology, measurement results, formulations for moisture absorption rate versus time and materials that are shortlisted for the future works.

## 1.6 Significant of Study

Understanding the current CRH and new plastic moisture absorption and moisture dissipation characteristic through this study will significantly assist the production in scraps and rework in terms of time and cost reduction for the overall tunable filter microcircuits production. Besides, the development of this study is also expected to increase the understanding plastic under study versus moisture characteristic and provides experiences in controlling moisture.

Moreover, rework and scrap after moisture absorption can be costly, therefore it was prudent to have a set of references to mitigate the moisture absorption and dissipation during tunable filter microcircuit process assembly and created a more robust and durable CRH with minimize latent failure overtime.

Furthermore, the finding of this research and the equations developed in this study will also serve as references data for future research development specifically in obtaining plastic moisture absorption and dissipation characteristics.

## 1.7 Research Planning

Gantt chart of the project had been planned as in Appendix A. The schedule may change according the time.