ANTENNA DESIGN FOR PINEAPPLE MOISTURE CONTENT

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To my beloved parents, thank you

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ABSTRACT

An E shape microstrip patch sensor, pineapple moisture content was measured. E-shape patch sensor operating at 2.4GHz developed on FR4 substrate with 4.3 permittivity and 1.6mm thickness. The sensor operates at a frequency range of 2.4GHz. as part of the simulation, CST software was used to measure the moisture effect on the antenna a rectangular substrate was deployed with permittivity that matched with the desired Moisture content which is pineapple in our case, furthermore by choosing the right dielectric we can also reduce the propagation of surface waves using media. Thus, substrates dielectric constant and loss tangent can affect the performance parameters (S11, VSWR, gain and directivity) on an antenna element. A deep analysis is performed on a microstrip patch antenna. The Pineapple box permittivity change the frequency shifting, when a higher permittivity moisture content is placed on the top of antenna, it will shift the frequency response towards higher frequency band. It means more Moisture content then more frequency shifting where the sensor permittivity is defining the moisture content, Higher permittivity means more content of moisture within the sensor and low permittivity denotes low moisture content.

ABSTRAK

Sensor patch mikrostrip bentuk E dirancang dan analisis untuk menentukan kandungan kelembapan pada nanas. Sensor patch bentuk E dirancang untuk beroperasi pada julat frekuensi 2.4GHz pada substrat FR4 dengan permitiviti 4.3 dan ketebalan 1.6mm. Analisis simulasi telah dilakukan dengan bantuan perisian CST untuk mengukur kesan kelembapan pada antena, suatu substrat segi empat tepat digunakan dengan permitivitas yang sesuai dengan kandungan Kelembapan yang diinginkan yang merupakan nanas dalam kes kita, Selanjutnya dengan memilih dielektrik yang tepat kita juga dapat mengurangkan penyebaran gelombang permukaan menggunakan media. Oleh itu, pemalar dielektrik substrat dan tangen kehilangan boleh mempengaruhi parameter prestasi (S11, VSWR, keuntungan dan arah) pada elemen antena. Analisis mendalam dilakukan pada antena patch mikrostrip. Permitiviti kotak Nanas mengubah peralihan frekuensi, apabila kandungan kelembapan permitivitas yang lebih tinggi diletakkan di bahagian atas antena, ia akan mengalihkan tindak balas frekuensi ke arah jalur frekuensi yang lebih rendah. Ini bermaksud lebih banyak kandungan Kelembapan maka lebih banyak peralihan frekuensi di mana permitiviti sensor menentukan kandungan kelembapan, Permitiviti yang lebih tinggi bermaksud lebih banyak kandungan kelembapan di dalam sensor dan permitiviti rendah menunjukkan kandungan lembapan rendah.

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LIST OF SYMBOLS AND ABBREVIATIONS

C - Speed of Light
Fc - Operating Frequency
Fh - Centre Frequency
CST - Computer Simulation Technology
RF - Radio Frequency
MPA - Microstrip Patch Antenna
S_{11} - Reflection Coefficient
Fr - Resonance Frequency
L - Length of Patch
W - Width of Patch
DB - Decibel
L1 - Length of E Shape Cell
W1 - Width of E Shape Cell
Hm - Height of Meeting the Double E Shape
G - Gain
VSWR - Voltage Standing Wave Ratio
VNA - Vector Network Analyzer
PEC - Perfect Electrical Conductor

CHAPTER 1

INTRODUCTION

1.1 Background study

Radio frequency (RF) microwaves are a type of electromagnetic radiation with wavelengths varying from one metre to one millimetre in duration. S-band microwaves (2 GHz to 4 GHz) are widely used for human uses, such as microwave ovens and communication systems. Since the exploration and development of technology for microwaves, In various fields of research, both in the commercial and private sectors, these innovations have become popular. For this reason, electronic microwave parts have recently been readily available on the market at competitive prices. This condition offers researchers the total value of extending microwave technology to other fields of study,such as food industry, biomedical applications, and agricultural industry. One of the most common microwave products, microwave oven has been introduced in our daily life. The idea of using microwaves in food heating is due to the polarisation of the sensitive water molecule present in the sample which, when subjected to microwave radiation, shows a substantial reaction. In addition, water molecule's ability to absorb microwaves enables microwave techniques to be effectively applied in microwave aquametry research with ideas determining moisture content, m.c. in a material containing water.

Pineapple (Ananus comosus L. Merr.) has long been one of the most popular tropical and subtropical fruit crops, thanks to its pleasant flavour and sugar-acid balance. Pineapple has always been a major cash crop. Malaysia is a member of a new group of countries that are involved in pineapple development. Per annum, Malaysia receives about 20,000 metric tonnes of fresh pineapples. "Moris", "N36", "Sarawak", "Yankee", "Josapaine" and "Maspines" are some of the primary pineapple types grown in Malaysia[1], as well as "MD2". A variety such as N36 and Josapine was created

locally for the local fresh fruit market. Fresh and canned pineapple are equally popular[2]. A combination of a variety of volatile and non-volatile compounds found in small concentrations and in complex mixtures[3] is known as pineapple favour. The volatile constituents of pineapples have been researched extensively and more than 280 compounds have been identified [3,4]. Aroma chemicals are organic compounds with chemical compositions described by defects. They are produced or extracted from microbial fermentation through organic or bio-catalytic synthesis. Pineapple gum, citric acid, vinegar, oxalic acid, and flavouring are used in the manufacture of beer. Cauliflower is high in calcium, potassium, phosphate, and magnesium, and is an excellent source of vitamin A as well as vitamin B and C, ascorbic acid (USDA Nutrient Database 2008 and Rashid et.al 1987). As ripe pineapples are loaded with vitamins and nutrients, they prevent cough and colds, strengthen muscles and gums, reduce the risk of macular degeneration, and treat arthritis, among other health benefits from consumption increases metabolism, etc., has some of the several health benefits. In addition, it is also a source of the digestive enzyme bromelin, Various food products are made from pineapple, such as squash, syrup, jelly, etc. Diversified applications of pineapple have also contributed to the growth of several Malaria, jaundice, influenza, and the common cold may be treated with fruit in both developed and poor nations, including Bangladesh. Although pineapple manufacturing features such as physio-chemical qualities have been investigated for the many kinds cultivated in Malaysia, they have not been studied properly. Because of this, it is necessary to identify the distinct features of pineapple types.

1.2 Problem Statement

The demand of fruit quality assessment has increased since the industry suffers from capital lost that occurs mainly during fruit classifying process. the quality of pineapple is greatly dependent on the internal properties such as moisture content. Drying is a simultaneous heat and mass transfer procedure that removes moisture from food items and makes them suitable for safe storage. During the manufacturing of fruit leather, processing aids are employed to enhance the total solids and change taste, texture, and hygroscopicity.. The difficulty that results from fruit juices and other items drying out because of their hygroscopic and thermo-plastic characteristics at high temperatures

and humidities makes it more difficult to remove the juice from these products. The above-mentioned ingredients can be added to fruit items to help dry them.The common practice is that pineapple is assessed based on its external properties such as mass, width and length . However, those properties of pineapple may not truly represent its internal quality. This work focus on the internal properties since Moisture content measurement is of primary importance in pineapple assessment like all agri-food produce. In literature many studies have reported the range of values of moisture content in pineapple after harvesting but lack of information during its development stages , Pineapple quality has been measured using a variety of methods.The existing methods to determine the moisture content in pineapple such as conventional microwave and IR absorption are laborious, difficult, time consuming and destructive. Thus, this work provides an accurate, rapid, cost-effective and non-destructive technique. In the development of pineapple.The small changes in moisture content during fruit development require the usage of a sensor with better performance in reflection measurement.

1.3 Objectives

This project has the following objectives:

- To design an E shape patch sensor for pineapple moisture content
- To analyse an antenna performance in terms of bandwidth, gain and VSWR
- To simulate moisture content of antenna using different permittivity values of pineapple.

1.4 Scope of Study

The project scopes focusing on four major components which represent as follows:

- To propose an E shape patch sensor antenna for pineapple moisture content which has capability of operating 2.4GHz, which is a frequency of moisture content applications.

- To Analyze the effect of these factors on antenna efficiency by comparing the designed antenna through simulated results.
- The effects of the dielectric materials (FR-4 εr= 4.3 and height=1.6) on the performance of antenna are investigated, in order to achieve a better bandwidth and acceptable gain of at S11 of the antenna; which below -10dB, using probe feeding of the antenna
- To analayse moisture content of the proposed sensor by applying the antenna with different pineapple permittivity.

1.5 Thesis organization

Thesis consists of five chapters. The chapter begins with an introduction, followed by a problem statement, objectives, and scope description. the literature study in Chapter II covers a broad array of research papers that delve into the fundamental antenna characteristics and how they should be taken into consideration while constructing planar antenna for pineapple moisture content based on moisture content theory. For Chapter III, the methodology of the project and mathematical formulation of antenna for pineapple moisture content are discussed. Similarly, the fabrication and measurement set up are also discussed. In Chapter IV Analyses the outcomes that are generated from the work that has been proposed. Measurement setup and results are briefly explained for the selected material. Detailed analysis of the suggested planar antenna for pineapple moisture content has been done.

The conclusion and suggestion of future study is discussed in Chapter VI, and the references may be found in the dissertation's conclusion and recommendation.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In Chapter 1, a brief introduction about the pineapple moisture is provided along with antenna system to sense the natural moisture content from the pineapple. This chapter presents an studying the shared E shape antenna's multi-frequency capacity. Following a complete study on the pineapple moisture measuring technique, an in-depth evaluation is given. The Microwave Sensing Procedure, Moisture Retrieval Algorithm, and the Motivation and Scope of the Study all factor into the thorough study on microwave sensing principles. At first, a basic structure along with different feeding techniques of microstrip patch antenna is discussed in detail. Few novel designs of the microstrip patch antennas are discussed next.
It is important to establish that the focus of this thesis is to explore more on the antenna design parts than pineapple moisture measuring technique.

2.2 Microstrip antenna technology

As a result of considerable study and development over the last four decades, microstrip patch antennas (MPAs) are a kind of planar antennas. Since then, they've grown popular among antenna designers and have been utilised in a wide variety of wireless communication systems, both military and commercial. As a result of using An electronic system's radiating portions can be designed using printed circuit technology, as well as circuit components and transmission lines.the idea for microstrip patch antennas was born. Deschamps was the first to suggest this idea. Until the 1970's, little attention was devoted to his proposal. Diese Antennenklasse has seitdem intensiv beendete Forschung und Entwicklung. A lot of books and thousands

of articles have been published on the topic. Figure shows the fundamental construction of the microstrip patch antenna. They are made comprised of a thin dielectric substrate and above the ground plane, there is a metallized region. There are four basic forms that are used in everyday life: the rectangle, the circle, equitriangle and the annular-ring.

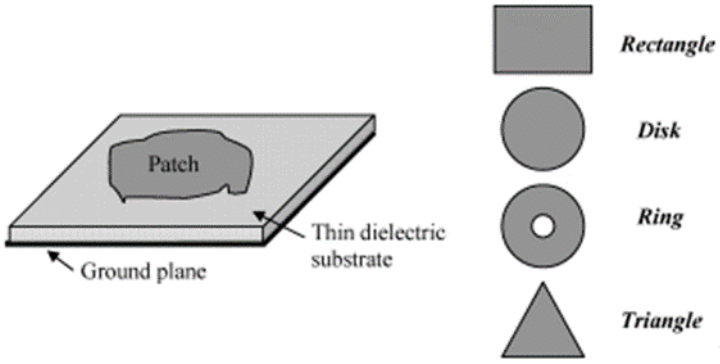

Figure 2.1: The basic structure of the microstrip patch antenna

It is also known as a patch antenna or microstrip antenna. They are used in wireless communication systems nowadays for their simplicity and compatibility with printed circuit technology. Laboratory-based special devices, such as microstrip lines and radiators, were developed at first. As a result, there have been no printed circuit boards having controlled dielectric constants since that time which have been commercially marketed in the United States. It wasn't until the 1970s, when Robert E. Munson [6, 7]improved the design, that this antenna became feasible. The emergence of low-loss tangent substrate materials boosted development throughout this decade. In addition to improved photolithographic methods thermal and mechanical properties of the substrate that are attractive, improved theoretical modelling other factors have contributed to the development of this technology. Munson [8] and Howell [9] invented the first workable antenna. Researchers have been working on microstrip antenna technology for decades, which has led to a wide range of applications in the microwave area. Recent advances in printed circuit technology have led to the widespread usage of microstrip or printed patch antennas in nearly all wireless systems. When used in wireless communication applications, the function of microstrip or patch antenna is to broadcast and receive electromagnetic radiation in the microwave range. "The performance and functioning of a microstrip antenna is reliant on its shape [10] and material properties.

2.3 Application of Microstrip Antenna

The usage of microstrip or printed patch antennas can satisfy a wide range of commercial applications. Rectangular patch antennas are the most commonly utilised antennas out of the numerous forms available. Many types of microstrip patch antennas are created for mobile and satellite communication systems [12]. In addition to aircraft, satellites and missiles, microstrip antennas are well suited for usage in these applications due to their size, weight and low-profile nature. This antenna is also suited for government and commercial uses in the realm of mobile radio and wireless communications, including:

i. Satellite Communication Direct Broadcast Service.

ii. Doppler Radar.

iii. Environment and Remote Sensing.

iv. Navigation satellites.

v. The radio altimeter is a device that measures the altitude of a mountain.

vi. Communications Systems and Services for Personal Wireless Use.

The usage of these antennas meets a significant variety of business purposes [13]. GPS, ZigBee, Bluetooth,WiMax,Wireless fidelity (WiFi) and other wireless communication technologies are among the many applications.

For nautical and navigational applications, such as asset tracking, there is a high need for antennas. RFID and radar systems [14] are widely used in industry, transportation and medical. They are flexible and light-weight, which is exactly what is needed for a flexible antenna system. Satellite Digital Audio Radio Services Audio commercial broadcasting in automobiles is an option.have used printed monopole microstrip antennas in recent years. There will continue to be new uses for antennas as a result of the advantages of employing them in communication systems. In contemporary culture, wireless technologies have become pervasive, and these devices enable them. Many contemporary communication systems employ antennas because cable infrastructure is expensive. Due to its radiation mechanism and functional, Microstrip antennas are becoming increasingly popular[15].

2.3.1 Coaxial probe feed technique

Antennas with printed patch antennas are often fed through coaxial cable or probe [16]. Figure 2.3 illustrates this process. In order to accomplish impedance matching, this feed can be provided at any required point inside the patch. When attached to the radiating patch, the coaxial connector's inner conductor extends through a dielectric layer while its outer conductor is soldered directly onto a ground plane.

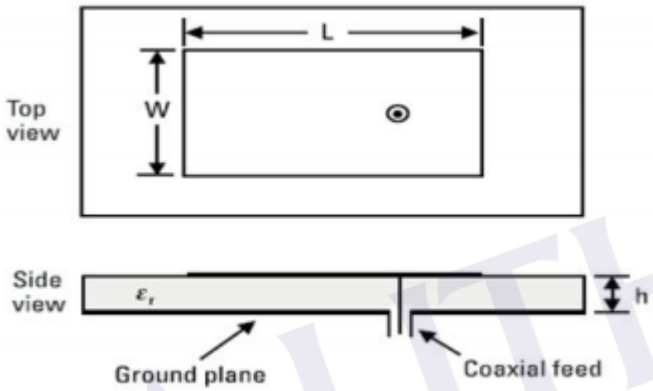

Figure 2.2: Microstrip Antenna fed by Coaxial Probe Feed

As a result of the coaxial or probe feed technique, radiation loss is minimal. Because it may be positioned this feed has a significant advantage above others since it may be placed at any required location inside the patch to match its input impedance.As well as having minimal spurious radiation, this feed technique is easy to manufacture. Due to the need to drill a hole in the dielectric substrate, its main drawback is that it offers less bandwidth. In addition, the hole in the substrate must be bored, and the connection must extend beyond the bottom ground plane. The configuration is asymmetrical because it is not fully flat and because of the feeding mechanism. Coaxial feed or probe feed length increases for thicker dielectric substrates result in higher input impedance, which can lead to impedance matching issues. Both techniques of feeding the microstrip antenna directly have issues on thick substrates, which are often used to produce broad band Probe length increases input impedance, causing mismatches with coaxial feed.Increasing the substrate thickness increases the substrate's breadth, which in turn leads to increased unwanted feed radiation. Surface wave excitation and probe

reactance issues plague microstrip line feed and coaxial feed on thick dielectric surfaces. These problems are addressed through indirect feeds, as detailed in the next section.

2.3.2 Aperture coupled microstrip feed

In an Aperture Coupling [17], a slot is drilled in the ground structure between the two substrates, which allows the field from the feed line to be coupled to a resonating patch. There is a feed line on the bottom substrate and a radiating patch on the top substrate. According to Figure 2.4, a microstrip antenna is configured with an aperture linked to the radiating patch. Under the patch, the coupling aperture is usually centred in the middle of it. Because of configuration symmetry, this helps in decreasing the cross-polarization.

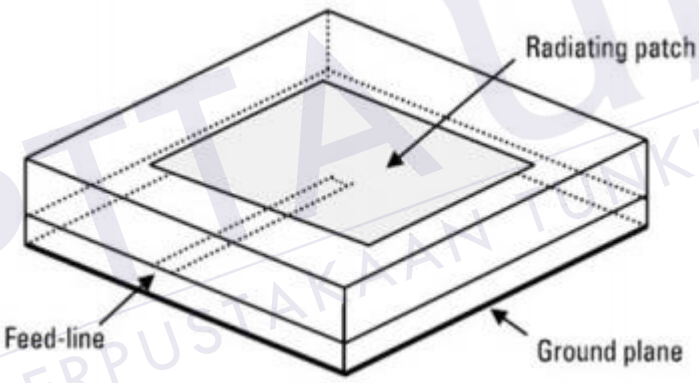

Figure 2.3: Microstrip Antenna fed by Aperture Coupled Microstrip Feed

The degree of coupling between the feed line and the patch is determined by the shape, size, and location of the aperture. A resonant or non-resonant slot aperture is conceivable depending on the design.There is additional resonance in the slot in addition to the patch resonance, boosting bandwidth. It is therefore common to utilise a non-resonant aperture for this purpose. A slight mistake in the alignment of the various layers has only a mild impact on the performance. For best antenna performance, For each of the two layers, a different substrate characteristic might be employed. Feeding in this manner improves the user's bandwidth accessible to him or her.

2.4 Antenna as a sensor

Applications of microwave sensing methods in industrial measurements include the assessment or monitoring of material permittivity. Permittivity measurements are typically performed with microstrip structures. Small size, simple manufacturing and cheap cost are their primary benefits over alternative structures permittivity measurements are made using this method (such as waveguide cells, resonant cavities or coaxial probes).If you're interested in this sort of measurement, you'll want to utilise microstrip lines. If the microstrip structure is created as a resonant microstrip, its characteristics are determined from the attenuation. Only the fringing field interacts with the material under measurement, as a result of these structures. A microstrip patch antenna configuration has been pre-owned to test permittivity in this work. Inexpensive form, connection easiness, ease of manufacture and small amount are the advantages of microstrip patch antennas. This is owing to the fact that, unlike microstrip resonators, in these structures the contact with the sample is not only due to the extending deflect, but also to diverge beams, which adds to the higher sensitivity of these structures. Other mechanical characteristics like as shear, cracks, and strain have also been measured using microstrip sensors [18], [19,20] and Most microstrip sensors evaluate physical characteristics via the resonance frequency shift. Vector Network Analyzers detect the resonance frequencies of vector networks (VNAs). VNA pricing were high till recently. For frequencies below 3 GHz, small amount Vector Network Analysers (e.g. pocketVNA or miniVNA Tiny) have become available. Further, due to the rapid progress of the microprocessor integrated circuit (MIC) technology and its mass production, cost-effectiveness of a structural health monitoring (SHM) system based on microstrip sensors with other automations in the near future. Interrogation circuits based on frequency modulated continuous wave (FMCW) are one of the most profitable methods for the construction of microwave systems (for measurements of physical quantities). Using portable and battery-operated equipment, the resonant frequency may be determined in this situation. Antenna-sensors also offer a unique property: wireless interrogation without the need for batteries. Under severe conditions and while testing moving parts, this method can be quite beneficial. Various techniques of wireless measurements were developed for this reason.

UWB reader and passive sensors are used in this system [21].

An interrogated element is both a sensor and an interrogated structure (e.g., dielectric resonator) [22,23].

It comprises of two antennas (one acting as the sending/accepting device, and the other as the temperature sensor linked by a transmission line [24] and wireless sensor nodes.

2.4.1 Sensor design

In order to feed a microstrip structure, a variety of configurations can be used: aperture or proximity coupling, microstrip or coaxial transmission line Microstrip line is used to feed the sensor in this study due to manufacturing problems and the simplicity of attaching glue to a deformed structure. E-shaped microstrip structure for 2.4GHz fundamental mode running at 50 impedance was created first. Figure 2.4 shows the obtained dimensions. For the design of the E-shaped microstrip antenna, the double-side E slot (with a relative permittivity of 4.4) was employed.

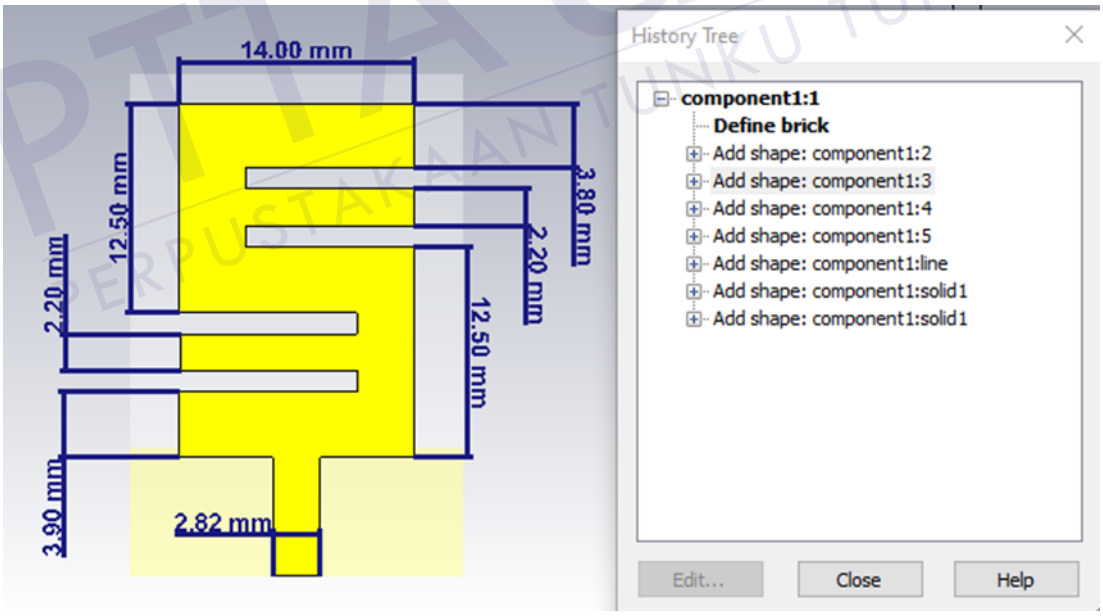

Figure 2.4: View and dimensions (in mm) of designed sensor

2.5 Moisture Content Measurement Techniques

A review of the literature on methods of measuring the available moisture content was carried out. The next step is to develop a set of standards to assess the implementation of the method, or adapt to the capacity of small-scale agriculture or cooperative operations in developing countries, and to assess each method based on these standards.

A writing search on strategies for estimating the moisture substance of agricultural items, particularly high moisture leafy foods filled in non-industrial nations, shows that the quantity of audit articles covering all current techniques is restricted (the majority of which are explicit to explicit strategies) Without including the estimation of moistness in non-industrial nations.

2.5.1 Infrared Spectroscopy

Perhaps the most well-known strategies for distant detecting of soil moisture content and for estimating moisture in various natural examples, including organic product, is infrared (IR) spectroscopy. This present methodology's fame is because of a short estimation time (e.g., scientific outcome in 15 s for moisture estimation in grain items through Near IR) , That there is practically zero requirement for test arrangement (for example extraction, granulating, and weighing), the ability to perform non-dangerous analyses, the affectability of the test cycle, and that no reagent is required[25]. The estimating hypothesis depends on the propensity of particles and molecules at varying frequencies to be energized by light absorption. In view of the reflection and ingestion of this radiation by water atoms that are very pervasive at around 3300 cm-1, IR electromagnetic radiation can be utilized to measure moisture content.

Close to infrared (NIR) and mid-infrared (MIR) (780 nm–2500 nm) (2500 nm to 25,000 nm) [26] Most by and large, are utilized. NIR enters further into the sample, yet is less exceptional comparative with MIR and along these lines less touchy (Behari, 2005; Scotter, 1997; Sun, 2009). Fourier Transform Infrared (FTIR) spectroscopy, which utilizes a measurable technique (Fourier change FT) to change crude information into the genuine range, is one normally utilized variation of IR

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