Academic Journal of Computing & Information Science
ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

Research Progress on Methods of Electromagnetic Wave Detection of Grain Moisture

Tingfeng Liu[1], Jianjun Wu[1,*] and Weifeng Zhu[2]

[1] College of Information Science and Engineering, Henan University of Technology, Zhengzhou 450001, China
[2] College of Science, Henan University of Technology, Zhengzhou 450001, China
[*]Corresponding author e-mail: 13939003632@163.com

ABSTRACT. *One of the important indicators of food storage safety is the grain moisture content. Non-destructive and accurate detection of grain moisture content is a goal that researchers in the grain storage safety industry have been pursuing. The methods of detecting grain moisture, namely the advantages and disadvantages of lossy and non-destructive methods, are summarized. The research status of electromagnetic wave detection methods of electromagnetic waves in different wavelengths such as near-infrared, terahertz and microwave is reviewed. This lays the foundation for selecting the best wavelength electromagnetic wave to detect grain moisture.*

KEYWORDS: *grain moisture, electromagnetic wave, near infrared, terahertz, microware*

1. Introduction

Moisture content is an important reference indicator for food. Most of the reason for grain deterioration is that the grain moisture content is not within the standard range, resulting in mildew or dry grains. Therefore, it is particularly important to use what method to quickly and accurately detect the moisture content of grain. There are many methods for measuring grain moisture, such as oven drying method, microwave heating method, infrared heating method, toluene distillation method, Karl. These methods must change the physical properties of food, and the detection takes a long time, is highly biased, and is susceptible to environmental influences. In recent years, electromagnetic wave technology has been widely used, and the use of electromagnetic waves to detect grain moisture has overcome many shortcomings of traditional methods. This paper summarizes the advantages and disadvantages of various methods for detecting grain moisture, and summarizes the current status of

ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

electromagnetic wave detection in different bands, which has important reference value for the practice of electromagnetic wave detection of grain moisture.

2. Comparison of Grain Moisture Detection Methods

The Grain and grain moisture detection technologies are divided into two types: lossy detection methods and non-destructive testing methods. The damage detection method requires changing the shape, structure or properties of the grain itself before testing. Loss detection methods include oven drying, microwave heating, infrared heating, toluene distillation, Karl. Fisher method, resistance method, etc.

(1) Loss Detection Method

1 oven drying method. The standard method is the 105℃ constant weight method. This method is to pulverize the grain into a certain fineness, and it is baked in an oven for 2 to 4 hours to volatilize the moisture in the grain, and the grain is sufficiently dried to ensure accurate results [1]. The advantage of this method is that it is easy to operate and low in cost. The disadvantage is that it takes a long time and the food needs to be crushed. 2 microwave heating method and infrared heating method. The microwave heating method and the infrared drying method are convenient to operate, and the energy consumption is low and fast. The disadvantage is that the food needs to be crushed and the surrounding environment will affect the measurement accuracy [2]. 3 toluene distillation method. Use the principle that water and toluene have different boiling points. The detection equipment is simple and easy to manage, but the reading is prone to errors. 4 Carl. Fei Xifa. This method is the most accurate chemical method for determining moisture content and can be corrected for other assays. The disadvantage is that the use of reagents is costly and there are reagent measurement errors, and the installation of the detection equipment is cumbersome. 5 resistance method. The advantage is that the equipment is simple and the cost is low. The disadvantage is that the detection accuracy is low, the test sample needs to be crushed, and it is susceptible to the variety of food, temperature and firmness.

(2) Non-destructive Testing

The non-destructive testing method analyzes the grain moisture content of the grain by using the nature of the grain, such as physical properties, optical properties and chemical properties, without destroying the grain [2]. Non-destructive methods include capacitance method, near-infrared method, nuclear magnetic resonance method and microwave method. 1 capacitance method. The principle is that the difference in grain moisture content results in different capacitances. The advantages are quick, fast and economical. The disadvantage is that the grain variety, material accumulation, temperature and season will affect the measurement accuracy. 2 near infrared spectroscopy. In the near-infrared spectrum, the absorption peak of water molecules is more. To detect the moisture content of the grain, it can be obtained according to the reflection intensity of water at a certain wavelength. The advantages are low cost, fast detection speed and relatively stable. The disadvantage is that detecting the inaccurate calculation model leads to errors in the measurement.

ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

3 nuclear magnetic resonance method. The method can determine the humidity in the medium by the degree of energy absorption. The advantage is that the detection is accurate and rapid, and the measurement range is wide. The disadvantage is the high cost of equipment maintenance and repair. 4 microwave method. The method utilizes the absorption of microwaves by food moisture to detect moisture. The advantages are safe, non-destructive, fast and accurate. The disadvantage is that it is easy to cause standing wave interference.

3. Electromagnetic Spectrum

The method of detecting grain moisture has its own shortcomings, and the non-destructive method has advantages compared with the lossy method. Electromagnetic waves have high frequency properties and are less sensitive to substances such as color, temperature, particle size and salt. After research and experimentation, in order to achieve convenient, non-destructive and accurate real-time detection, the most suitable way is to detect grain moisture through electromagnetic waves. It can be known from Maxwell's equations that the propagation of electromagnetic waves is affected by the spatial medium, and the propagation characteristics of electromagnetic waves of different wavelengths are very different. According to the frequency, electromagnetic waves are divided into radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X-rays, etc. [3]. The electromagnetic spectrum is shown in Figure 1.

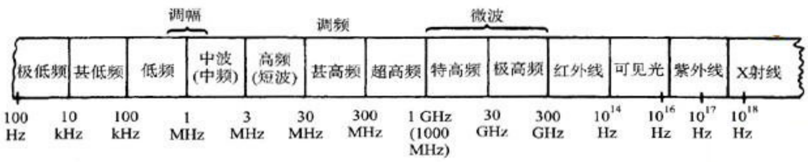

Figure. 1 Electromagnetic spectrum

4. Research Status of Detection of Grain Moisture by Electromagnetic Waves in Different Bands

4.1 Using Near Infrared to Detect Grain Moisture

Do Near Infrared (NIR) is between visible light (VIS) and mid-infrared light (MIR) and is an electromagnetic wave with a wavelength in the range of 780 to 2526 nm. Near-infrared photons are easily absorbed by chemical bonds, such as O-H, which makes it easy for water molecules to absorb near-infrared light through fundamental frequency, frequency doubling, and frequency multiplexing. The frequency spectrum of the near-infrared region is high and stable. Near-infrared spectroscopy can be used for qualitative analysis or quantitative judgment, and data

ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

analysis is fast, so near-infrared spectroscopy can be used to analyze grain moisture content [4].

Xiao Zhitao [5] obtained grain spectral data with different water gradients in the near-infrared band through a grain moisture detector designed based on the principle of near-infrared spectroscopy, and then adopted partial least squares (PLS) and competitive adaptive weighting algorithm. (CARS for short) data analysis method selects the characteristic band of grain in the near-infrared region, analyzes the grain moisture, and completes the BP neural network model calibration test and instrument performance test of rice, and obtains the water calculation model. Zhang Yurong et al [6] used BP neural network combined with near-infrared spectroscopy to detect the moisture content of wheat. The national moisture content of the wheat was determined as the BP neural network target vector. Each sample was scanned to obtain the sample spectrum, and the pre-treated spectrum was analyzed by data analysis and principal component analysis to establish a BP neural network model for predicting the moisture content of wheat. [7].

4.2 Using Terahertz to Detect Grain Moisture

Terahertz (THz) refers to electromagnetic waves with a frequency between 0.1 THz and 10 THz, between microwave and infrared. Terahertz waves have broadband, low energy, non-destructive, high sensitivity, high signal to noise ratio, and good stability. Terahertz can penetrate non-metallic substances, low scattering, low intrusion, strong absorption of polar water molecules [8], and has great potential for highly sensitive detection of moisture.Ma Pin, Yang Yuping [9] applied the terahertz spectroscopy technique to the determination of the moisture content of Chinese medicinal materials, and used ordinary gastrodia as an example to measure its moisture content. The higher the water content of gastrodia, the higher the terahertz frequency, and the tianma to terahertz. The greater the absorption rate, this reflects the fact that terahertz is very sensitive to moisture in the gastrodia elata sample. However, if the frequency is too high (>1.5 THz), the signal-to-noise ratio will become smaller. In practice, the THz frequency should be correctly selected to reduce the error. The state of the water content of the sample is evaluated based on the relationship between the absorption coefficient and the frequency. Liu Huan, Han Donghai [9] detected the moisture content in biscuits by terahertz time-domain spectroscopy (THz-TDS) technique. The time domain spectrum acquired by the transmissive terahertz system is Fourier transformed, and the Fresnel formula is used to obtain the refractive index and absorption coefficient spectrum. Principal component regression analysis (PCR) and partial least squares (PLS) are established. The model calculates the water content and works well.

4.3 Using Microwave to Detect Grain Moisture

The microwave is an electromagnetic wave having a frequency of 30 MHz to 300 GHz. Compared with radio waves in other bands, microwaves have high-frequency characteristics. As the frequency increases, microwaves are

ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

attenuated by moisture absorption in the grain pile propagation; microwaves have good penetrability and can penetrate deep into the material and the molecule interacts with the atom to detect the internal structure of the substance.

There are many studies on the use of microwaves to detect grain moisture. According to published literature, Samir Trabelsi and Ana M. Paz [10] proceeded from the free-space measurement of the dielectric properties of peanut shell pellets at microwave frequencies, on peanut shell pellets. The moisture content and bulk density were tested non-destructively. For the determination of moisture content, a function based on permittivity is used which allows moisture content prediction independent of bulk density by measuring the dielectric properties at microwave frequencies. Li Junlin, Zhang Yuan [12] and others used the microwave reflection method to detect the whole grain in the granary in real time, and designed the online measurement system of grain moisture. Based on the power ratio measured by the system, the attenuation of the power is related to the dielectric constant of the grain. The constant is proportional to the moisture content of the grain, and the moisture content of the grain is calculated by the formula. Jiang Yuying et al [13] used the carrierless pulse radar (the electromagnetic wave propagates in the form of no carrier pulse) to penetrate the water-containing food process to produce energy attenuation, phase shift, or changes in the transmitted wave parameters, by studying the attenuation of the electromagnetic wave reflected echo signal. The amount of grain moisture is converted, and the attenuation calculation model of ground-penetrating radar without carrier pulse electromagnetic wave in the process of grain storage is proposed.

5. Analysis of Grain Moisture in Different Environments

5.1 Near Infrared

Advantages of near-infrared spectroscopy: (1) Fast, usually can give analysis results in a few minutes or even tens of seconds, can be analyzed online; (2) simple sample preparation; (3) large amount of information, Simultaneous determination of multiple components; (4) calibration modeling, no other conventional chemical analysis methods, no toxic organic reagents, no pollution; (5) non-destructive testing of products; (6) optical fiber can be used to achieve remote Riddle.

The modeling equations for detecting grain moisture using near-infrared technology include linear regression equations and nonlinear regression equations. Linear equation modeling (partial least squares, modified partial least squares, principal component regression) is transformed into BP neural network analysis. The mode improves the accuracy of the test. Based on near-infrared spectroscopy, there are many calculation models for determining grain moisture, but large-scale applications have not yet been realized. Near-infrared spectrometer for detecting grain moisture by benchtop moisture analyzer or portable moisture analyzer, such as Zeltex's ZX-880 near-infrared detector, Perten's rapid component analyzer and whole grain analyzer, etc. These instruments not only detect moisture, but also

ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

detect proteins, fats, amino acids and other ingredients. Suitable for the measurement of powdery, granular samples. However, such instruments are expensive and suitable for use in medium and large grain storage laboratories.

5.2 Terahertz

As a spectrum resource that humans have not fully recognized and utilized so far, terahertz is considered to have great scientific prospects. Terahertz waves have many advantages such as broadband, low energy, non-destructive, high sensitivity, high signal to noise ratio, and good stability. Since many biomolecules vibrate in the terahertz band, in the field of food testing, the use of terahertz for the detection of sugars, proteins, amino acids, moisture and other substances has great advantages. Because terahertz is very sensitive to moisture and scatters smaller than the near-infrared and visible-light bands, and compared to the infrared spectrum, terahertz radiation has a longer wavelength and better penetration, so terahertz can be used to detect small differences in moisture. Terahertz detects the potential of grain moisture in the future. Existing products such as ZOMEGA Z3 laboratory-grade terahertz time-domain spectroscopy and imaging system (THz-TDS); Terasys 4000 terahertz time-domain spectrometer from Rainbow Photonics, Switzerland; TDS10XX, FC TDS and TDS (1060nm from BATOP, Germany) Femtosecond lasers) and their imaging systems. These existing products are imported from abroad and are expensive and are temporarily suitable for laboratory research.

5.3 Microwave

The advantages of microwave detection of moisture: (1) insensitive to the pH and conductivity of the tested food; (2) measurement of free water and combined water, the results are more representative; (3) non-contact measurement, will not Wear equipment, will not stick to food, will not affect the operation process; (4) high measurement accuracy; (5) maintenance-free, low operating cost; (6) low emission energy, will not change the nature of food, safe and reliable; (7 It is not affected by dust and water vapor in the environment, and has strong anti-interference ability, and is not affected by changes in grain color and sunlight.

Microwave moisture products include Germany's latest online moisture meter, MOSYE's Ms-a-101 online moisture meter, Zhuhai MC-7825G moisture meter, Japan SK-300 portable moisture meter and Germany's RGI microwave online moisture meter. The US Department of Agriculture and the Swedish company Botong developed the 5100 Rapid Moisture Analyzer to measure the moisture content of grain and oil using 150MHz RF radio waves [13]. It uses a calibration curve that needs to be updated to suit various grain and oil moisture. The measurement can also measure the bulk density and temperature with a high degree of accuracy. These products have high measurement accuracy and are expensive, and are not suitable for grain purchase and storage site use. They are generally used as online moisture detection equipment for production lines. Ground penetrating

ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

radar can also be used as granary storage grain moisture detection, but since the granary is a large, closed, multi-layered medium architecture, the theoretical model of the finder radar needs further research, and its practical application needs to be investigated.

6. Conclusion

Studying a fast, accurate, non-destructive method for detecting the moisture content of grain has always been an important issue. Due to the non-destructive nature of electromagnetic waves, anti-interference, frequency bandwidth, and many limitations of traditional methods, electromagnetic waves have been used in many applications in detecting grain storage in recent years. This paper describes the current status of research on the method of detecting grain moisture, and analyzes the characteristics of near-infrared spectroscopy, terahertz time-domain spectroscopy, microwave and other electromagnetic waves in different bands and their adaptation scenarios. The application of near-infrared spectroscopy is relatively mature, suitable for detecting a small amount of grain samples; the terahertz time-domain spectrum is in the preliminary research stage; microwave can measure a small amount of grain samples with a moisture analyzer, and can also detect the moisture content of grain in a large granary by using ground penetrating radar. The application of electromagnetic waves to grain detection requires more theoretical research and research practice. How to select the best electromagnetic wave band for accurate measurement of grain moisture online remains to be further studied.

Acknowledgments

This work was supported by national ministry of science and technology project (2018YFD0401404)

References

[1] Zhou Xianqing, Zhao Xilei, Zhang Yurong, et al. Current status and prospects of grain moisture detection technology [J]. Grain Processing, 2015 (4): 29-34.
[2] Zhao Jing, Huang Caojun, Li Bozhi. A Review of Methods for Detection of Grain Moisture Content [J]. Agricultural Technology and Information, 2018, No.549 (16): 48-51.
[3] Bi Gang. Electromagnetic Field and Microwave [M]. Zhejiang University Press, 2006.
[4] Fan Weiyan, Xing Wei, Lin Jiayong. Study on Rapid Determination of Water Content in Rice by Near Infrared Spectroscopy [J]. Grain, Oil and Food Technology, 2008, 16 (5): 49-52.
[5] Xiao Zhitao. Development of grain moisture detection instrument based on near infrared spectroscopy [D].

[6] Zhang Yurong, Fu Ling, Zhou Xianqing.Near-infrared detection method for wheat water content based on BP neural network [J]. Journal of Henan University of Technology (Natural Science Edition), 2013, 34 (1): 17-20.
[7] Yan Zhanke, Zhang Hongjian, Ying Yibin.Application of THz Technology in Agricultural Products/Food Quality Testing[J].Spectroscopy and Spectral Analysis, 2007, 27 (11).
[8] Ma Pin, Yang Yuping.Detecting the moisture content in Gastrodia by terahertz spectroscopy [J]. Journal of Terahertz Science and Electronics Information, 2017 (1).
[9] Liu Huan, Han Donghai. Quantitative Analysis of Biscuits Moisture Based on Terahertz Time Domain Spectroscopy [J]. Journal of Food Safety & Quality, 2014 (3): 725-729.
[10] Trabelsi S, Paz A M, Nelson S O.Microwave dielectric method for the rapid, non-destructive determination of bulk density and moisture content of peanut hull pellets [J]. Biosystems Engineering, 2013, 115 (3): 332-338.
[11] Trabelsi S, Kraszewski A W, Nelson S O.Nondestructive microwave characterization for determining the bulk density and moisture content of shelled corn [J]. Measurement Science and Technology, 1998, 9 (9): 1548-1556.
[12] Li Junlin, Zhang Yuan, Lian Feiyu. Study on Microwave Detection of Grain Storage Technology [J]. Grain and Oil Processing, 2007 (9).
[13] Jiang Yuying, Zhang Yuan, Ge Hongyi.Study on the Propagation Attenuation Characteristics of Electromagnetic Wave in Grain Storage Grains [J]. Grain and Oil Processing (Electronic Version), 2010 (7): 59-61.
[14] Nigmatullin R R, Nelson S O. Recognition of the "Fractional" kinetics in complex systems: dielectric properties of fresh fruits and vegetables from 0.01 to 1.8 GHz [M]. Elsevier North-Holland, Inc.2006.
[15] Andrea Hercegová, Milena D?m?t?rová,Eva Matisová. Sample preparation methods in the analysis of pesticide residues in baby food with subsequent chromatographic determination [J]. Journal of Chromatography A, 2007, 1153 (1-2): 54-73.
[16] Gilmore C, Asefi M, Paliwal J, et al. Industrial scale electromagnetic grain bin monitoring [J]. Computers and Electronics in Agriculture, 2017, 136: 210-220.
[17] Lawrence K C, Windham W R, Nelson S O.WHEAT MOISTURE DETERMINATION BY 1- TO 110-MHZ SWEPT-FREQUENCY ADMITTANCE MEASUREMENTS [J]. Transactions of the ASAE, 1998, 41 (1): 135-142.
[18] Nelson S O.Moisture-Dependent Kernel- and Bulk-Density Relationships for Wheat and Corn [J]. Transactions of the ASAE, 1980, 23 (1): 0139-0143.
[19] Liu X, Chen X, Wu W, et al. A neural network for predicting moisture content of grain drying process using genetic algorithm [J]. Food Control, 2007, 18 (8): 0-933.
[20] Hu J, Wang Z, Wu Y, et al. Rapid determination of the texture properties of cooked cereals using near-infrared reflectance spectroscopy [J]. Infrared Physics & Technology, 2018, 94: 165-172.

ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

[21] Phetpan K, Sirisomboon P. Evaluation of the moisture content of tapioca starch using near-infrared spectroscopy [J]. Journal of Innovative Optical Health Sciences, 2015, 08 (02): 1550014.
[22] Tahir A R, Neethirajan S, Jayas D S, et al. Evaluation of the effect of moisture content on cereal grains by digital image analysis [J]. Food Research International, 2007, 40 (9): 0-1145.
[23] Chua H S, Haigh A D, Thompson F, et al. Measurement of the wet-mass, moisture content, volume and density of single wheat grain kernels [J]. IEE Proceedings-Science, Measurement and Technology, 2004, 151 (5): 384-0.
[24] Chua H S, Haigh A D, Parkinson G, et al. An Instrument to Measure the Characteristics of Single Wheat Grain Kernels [C] // Microwave Conference, 2006. 36th European. IEEE, 2006.
[25] Kraszewski A W, Nelson S O.Microwave resonator for sensing moisture content and mass of wheat kernels [C] // American Society of Agricultural Engineers Meeting. 2018.
[26] Al-Mahasneh M A, Rababah T M. Effect of moisture content on some physical properties of green wheat [J]. Journal of Food Engineering, 2007, 79 (4): 1467-1473.
[27] Berbert P A, Stenning B C. On-line Moisture Content Measurement of Wheat [J]. Journal of Agricultural Engineering Research, 1996, 65 (4): 287-296.
[28] Trabelsi S, Kraszewski A W, Nelson S O. A microwave method for on-line determination of bulk density and moisture content of particulate materials [J]. IEEE Transactions on Instrumentation and Measurement, 1998, 47 (1): 127-132.
[29] Jiang Yuying. Inversion of moisture content in wheat outside the electromagnetic wave warehouse [D]. Henan University of Technology, 2010.
[30] Zhang Xinxin. Research on electromagnetic wave detection method for density distribution under granary storage and water balance conditions [D]. Henan University of Technology, 2014.
[31] Lian Feiyu, Li Qing. Study on the determination of water distribution in large grain piles by dielectric constant method [J]. Computer Engineering and Applications, 2012, 48 (35): 19-24+84.
[32] Lian Feiyu. Research on electromagnetic wave detection theory and method for moisture distribution of large warehouse storage grain [D]. Shanghai University, 2012.
[33] Yu Zhangming. Application of RIS-K2 radar technology to detect moisture permittivity of storage grain [D]. Henan University of Technology, 2011.
[34] Wang Yijin. Research on electromagnetic wave detection method for moisture in reflective transmissive grain storage grain [D]. Henan University of Technology, 2012.
[35] Yu Zhangming, Zhang Yuan, Fu Maixia, Wang Yijin. Application of Radar Electromagnetic Wave Technology to Detect Water Dielectric Constant of Stored Grain [J]. Grain and Oil Processing, 2010 (10): 68-71.
[36] Wu Caizhang. Microwave-based Grain Moisture Intelligent Tester [J]. Instrument Technology and Sensors, 2010 (11): 25-26+29.
[37] Xing Chao. Study on the application of electromagnetic waves to detect grain moisture [D]. Xidian University, 2009.

ISSN 2616-5775 Vol. 2, Issue 2: 49-58, DOI: 10.25236/AJCIS.010038

[38] Li Xingning, Liu Rongjin, Chen Zhen, Wang Shujie, Liu Yongsheng. Research on Microwave Detection Method of Grain Moisture [J]. Science and Technology Information, 2017, 15 (17): 55-56.

[39] Wei Liguo, Zhang Xiaochao, Hu Xiaoan, Li Fuchao. Microwave online grain moisture detection system [J].Journal of Agricultural Mechanization Research, 2009, 31 (06): 145-147.

[40] Sun Jian, Zhou Zhanming, Tang Huaijian. Research on Rapid Detection Method of Grain Moisture at Home and Abroad [J]. Grain Storage, 2007 (03): 46-49.

[41] Liang Yan. Discussion on Determination of Grain Moisture by Near Infrared and Conventional Method [J]. Food Safety Guide, 2016 (Z2): 74-75.

[42] Fu Ling. Research on Rapid Determination and Evaluation Technology of Wheat Quality [D]. Henan University of Technology, 2013.

[43] Zhang Jun. Application Research of Near Infrared Spectroscopy Testing Technology in Grain Analysis [D]. Graduate School of Chinese Academy of Sciences (Changchun Institute of Optics, Fine Mechanics and Physics), 2005.

[44] Ma Wei, Cheng Li, Shan Yi, Wang Haibo, Wei Shujuan, Yang Chunyu. Progress in the application of terahertz science and technology in the field of food quality and safety [J]. Meat Research, 2015, 29 (11): 39-43.

[45] Bu Zhengyan. Research on crop leaf moisture detection method based on terahertz imaging technology [D]. Jiangnan University, 2018.

[46] Zhao Zhongyuan. Non-destructive testing of wheat quality based on THz technology [D]. Henan University of Technology, 2016.

[47] Li Bin, Du Xiuyang, Liu Yande, Hu Jun. Study on the detection of potato powder with terahertz time domain spectrum [J/OL]. Progress in laser and optoelectronics: 1-14 [2019-06-17].

[48] Vyacheslav A. Trofimov. About influence of effect of multi-playing of frequency for broadband THz pulse on detection and identification of substances [P]. Security + Defence, 2018.

[49] M. Ramesh (2014). Design, development, and deployment of a wireless sensor network for detection of landslides. Ad Hoc Networks, vol.13, no.1, p.2-18.