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Preliminary Experiments for Detecting Soft Foreign Materials in Seaweed using Sub-Terahertz Radar

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***Abstract*— Hygiene management of processed food is very important for human health. Many food manufacturers perform surface inspections for separation of food and foreign materials during manufacturing phase. However, many kinds of foreign materials are also found inside food. For this problem, a method of penetration inspection for packaged products is required. The conventional penetration inspection using X-ray and metal detector can only detect metals and hard materials while soft foreign materials such as worms, cannot be detected. In this paper, we propose a method of penetrating packaged food using sub-terahertz radar which can detect even soft foreign materials. The signal of 0.1 THz(Terahertz) frequency radar module in the proposed system can penetrate both food and foreign materials in low moisture environments. Since the signals acquired by sub-THz radar are not uniform in intensity and contain a lot of noise, we also provide a preprocessing solution to mitigate them. Through an experiment, it was proved that the worms in 100 pieces of packaged seaweed were successfully detected.**

***Keywords*— Terahertz, food safety, foreign material detection**

I. INTRODUCTION

Since most foods are basically consumed by humans, hygiene management is very important. Although many safety management techniques have been proposed for workers in the food manufacturing process, the occurrence of foreign material inside food is still an unresolved problem. For example, the conventional method of naked eye inspection has several limitations such as low accuracy and low processing speed. To tackle this, recently, non-destructive and fully automated testing techniques are attracting attention for food inspection. As for surface inspection methods of food, vision inspection using machine vision camera [1] and spectroscopic inspection using a hyperspectral camera [2] are representative solutions. However, these method are effective only in the manufacturing or cooking stage, and it is difficult to detect foreign materials inside the food after packaging is completed. In particular, some insects such as Plodia Interpunctella have been reported to penetrate packages of food in storages or warehouses. Penetration inspection methods such as x-ray inspection [3] and metal detector [4] mitigate these problems. However, these inspection methods can only detect hard foreign materials and sometimes soft foreign materials are more dangerous than hard ones. Therefore, a method for detecting soft foreign materials inside food is crucial issue. To this end, in this paper, we propose a noble non-destructive detection system with terahertz electromagnetic waves. This wave refers to an electromagnetic wave in the range of 0.1 THz to 10 THz. Terahertz waves have lower transmittance than microwaves but high resolution, and lower resolution than light waves but high transmittance [5]. Although Terahertz waves can basically detect internal objects by penetrating materials, there is a limit to penetrating food containing moisture due to strong interaction with moisture. Thus, when food is selected in consideration of this characteristic, foreign materials inside the food can be successfully detected [6].

II. MATERIALS AND EQUIPMENT

A. Materials

As the selection criteria for the target food, we choose seaweed considering the fact that it has low moisture and moderately thick bundle packages. Dried seaweed is one of the representative traditional food in Korea and consumed worldwide. The main product of dried seaweed is packaged in 100 sheets bundle. In Korea, the unit of 100 sheets of dried seaweed is called ‘tot’. A tot of dried seaweed has a moderate thickness and low moisture content. Therefore, it is very suitable for penetrating inspection using terahertz waves. For performance evaluation, we conducted an experiment to identify the worms in a tot of seaweed.

B. Equipment

The terahertz radar used in the experiment has a frequency of 0.1 THz. A terahertz below 1THz is also called sub-terahertz. The equipment consists of a source that transmits terahertz waves and a scanner that receives them. The scanner has adopted a line scan type scanner for application to food manufacturing sites. This makes it possible to inspect food moving at high speed on a conveyor belt. The specifications of the terahertz source and scanner can be shown in Table 1.

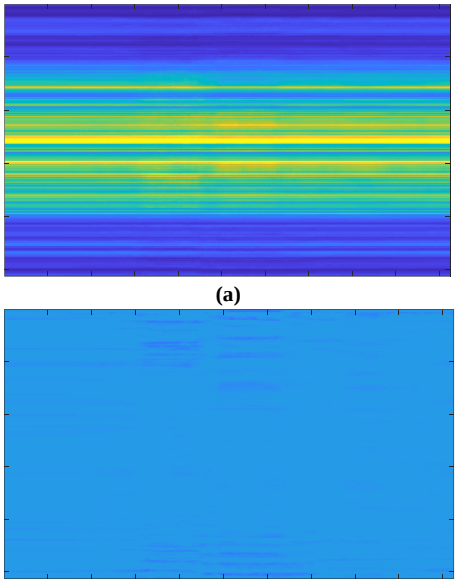
TABLE I. SPECIFICATIONS OF THE TERAHERTZ RADAR

Source	
Frequency	0.1 THz
Power	100mW
Scanner	
Number of pixels	256
Pixel size	1.5 x 3 mm^2
Dimensions of device	450 x 160 x 44 mm^3

Image acquisition rate	5000 fps

III. PREPROCESSING METHOD

The intensity of signals acquired with terahertz scanner is not uniform. This problem can be confirmed through Figure 1-(a), which show the background raw signal. To solve this problem, the average value of each line is multiplied by a coefficient that makes the global average value. A signal with uniform intensity after background correction can be seen in Figure 1-(b).



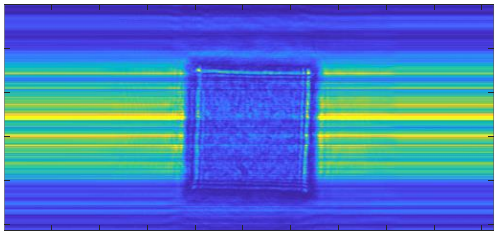
(a) **(b)**

Fig. 1. Background signal (a) Raw signal (b) After background correction

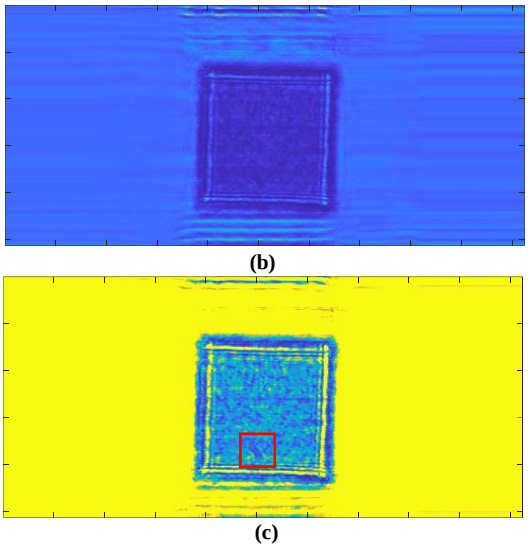
IV. EXPERIMENTAL RESULT

The food used in the experiment was a tot of seaweed and mealworm is used as soft foreign material. A 30mm long and 4mm thick mealworm was inserted inside the seaweed package. The raw signal of seaweed can be checked in Figure 2-(a) and the enhanced signal can be seen in Figure 2-(b) with background correction. However, even when background correction is applied, the difference in signal intensity between the background and the seaweed is large and the difference in signal strength between the seaweed and the mealworm is small, so that the mealworm is not properly identified.

In order to solve this problem, if the value of the background area is removed by thresholding, the range of the value is reduced, so that the mealworm can be identified accurately. The threshold removal signal can be seen in Figure 2-(c) and the location of the mealworm is indicated by a red box.



(a)



(b) **(c)**

Fig. 2. Seaweed penetration inspection (a) Raw signal (b) After background correction (c) After threshold removal

V. CONCLUSION

The purpose of this research is a preliminary experiment for the development of a food penetration inspection system using terahertz waves. When selecting the target food, it is necessary to consider whether the moisture content is low and the thickness that allows terahertz waves can penetrate. In the experiment, the unbalanced signal intensity was corrected through background correction, and the visibility of foreign materials was increased through threshold removal.

Through this study, an enhanced terahertz signal was obtained and the possibility of detecting foreign materials was confirmed through an experiment. In future research, we will develop a faster foreign material detection system by training the enhanced signal with a neural network.

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