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Terahertz Transmission Images For Medical Applications

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1. Introduction

Currently, x-ray is mostly used for the diagnosis of dental cavity and osteoporosis. The osteoporosis is broadly defined as a decrease in the amount of bone mass per unit volume of the bone. Clinically the manifestation of low bone mass presents a clinical problem to the general population as an increase in fracture risk and especially in aging population[1]. Although the amount of the irradiated x-ray to the human body for the clinical diagnosis is relatively small, the exposition of the x-ray to the human body should be minimized as much as possible, since the x-ray is an ionizing radiation. To investigate other possible systems replacing X-ray, ultrasonic imaging and MRI(Magneto-Resonance-Imaging) systems were studied. Unfortunately, an effective and safe diagnosis tool for detecting the dental cavity and the osteoporosis is currently lacking.

In this paper, we present potential medical applications of terahertz transmission imaging system for the diagnosis of the dental cavity and the osteoporosis. In the proposed terahertz transmission image system, clinical information is successfully obtained including the density of dentin, the electrical properties of dentin, the composition of tooth, and locations and size of the cavities. Internal pulp cavity and external cavities were clearly observed in the terahertz images. Also, this technique has demonstrated potential medical applications, monitoring bone fracture, bone diseases such as, osteoporosis and arthritis, and diseases that originate in or affect bone marrow. Density distributions of the marrow were acquired, showing the clear images of air-space and bone-grid inside the marrow. Even though the obtained terahertz images did not exhibit the best resolutions compared to the X-ray images, the terahertz images were further improved using state-of-art digital data processing technique, called neural network algorithm. In addition, we have extracted electrical parameters (permittivity and conductivity) from a sliced tooth and a sliced bone between 100GHz and 1THz.

2. Diagnosis of Dental Cavity

Figure 1(a) shows a terahertz transmission image of a dental pulp cavity. For comparison, photograph and X-ray image are shown together. Generally, dental pulp cavity provided information for health and growth of the tooth. In the terahertz image of Figure 1(a), the dental pulp cavity is clearly shown in circle. In the terahertz image, the cavity is shown as a brighter part, implying that terahertz pulse is more transparent to the cavity since the terahertz pulse is absorbed by the conductivity of dentin. In figure 1(b) shows vertical image of a decayed tooth. Both amalgam coverage and a cavity can be observed in the terahertz image. The amalgam is a kind of compositional metal. The amalgam and cavity is found quite contrastive in the terahertz image comparable to the x-ray image. The spatial resolution of the terahertz image is about 500μm. Figure 1(c) shows the extracted electrical parameters of a sliced tooth whose thickness is 1.1mm in the dentin part. The conductance of the dentin were observed in the terahertz frequency spectrum region. The parameters can be further used for estimating the density of the dentin from the measured terahertz waveforms. During the parameter extraction, genetic algorithm was used for time-domain data fitting. Extracted model parameters were well matched to the terahertz measurement. And the degree of attenuation with and without a sliced tooth sample is well matched with the extracted conductivity. The auto-correlation coefficient between the measured terahertz pulse is 0.97, which means that the extracted electrical parameters are pretty accurate.

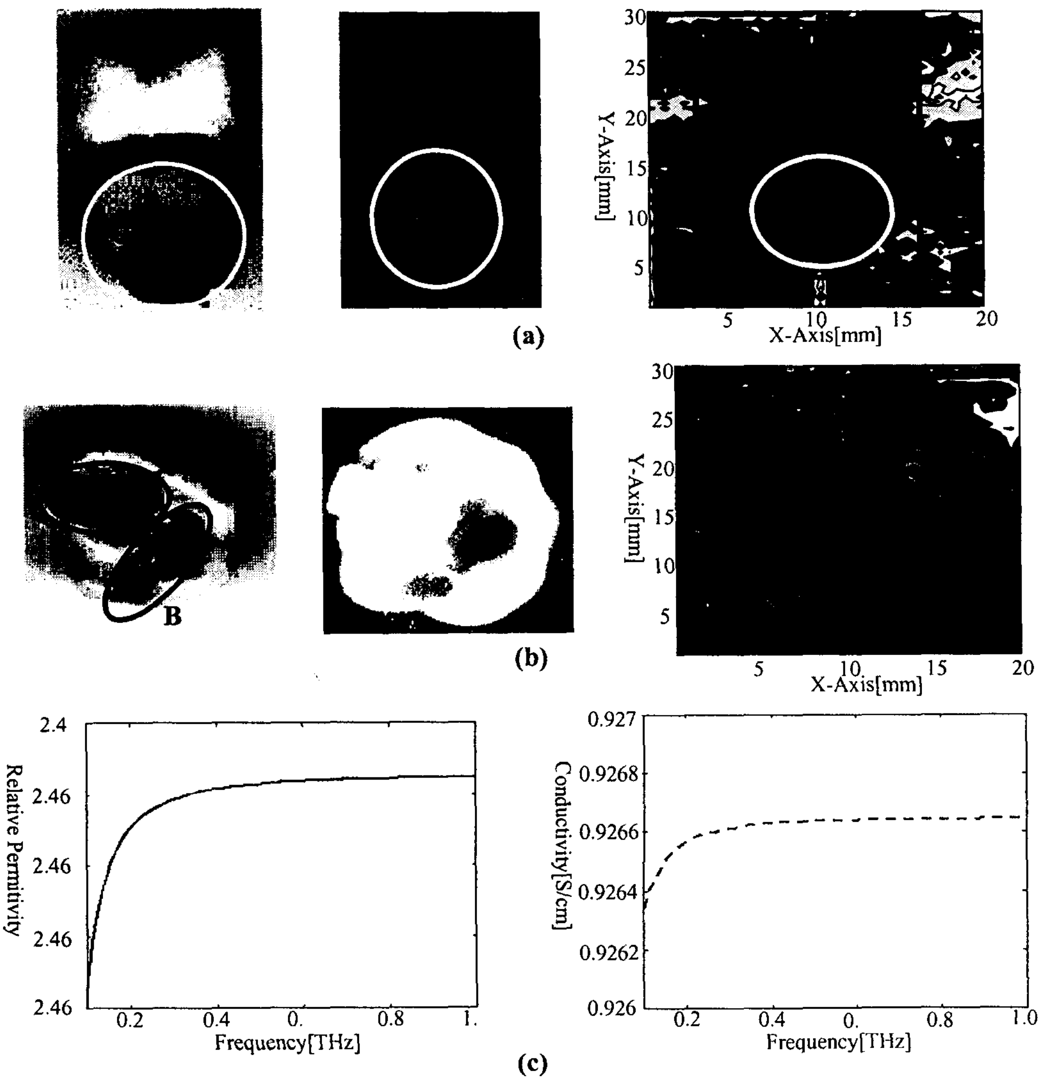

Fig. 1. (a) Terahertz dental image of internal pulp cavity. Photograph and X-ray image are shown for comparison. (b) Terahertz dental image of external cavity. Photograph and X-ray image are shown for **comparison. (c) Extracted**

3. Diagnosis of Osteoporosis

Figure 2 shows the terahertz transmission image of head part of a rib bone and the extracted electrical parameters of a sliced bone. In the figure 2(a), a part of low marrow density region are shown in a circle. The photograph are showing only surface marrow density. On the other hand, the terahertz transmission image is showing density information inside the bone. Figure 2(b) shows the extracted electrical parameters of a sliced cortical part of the bone whose thickness is 0.85mm.

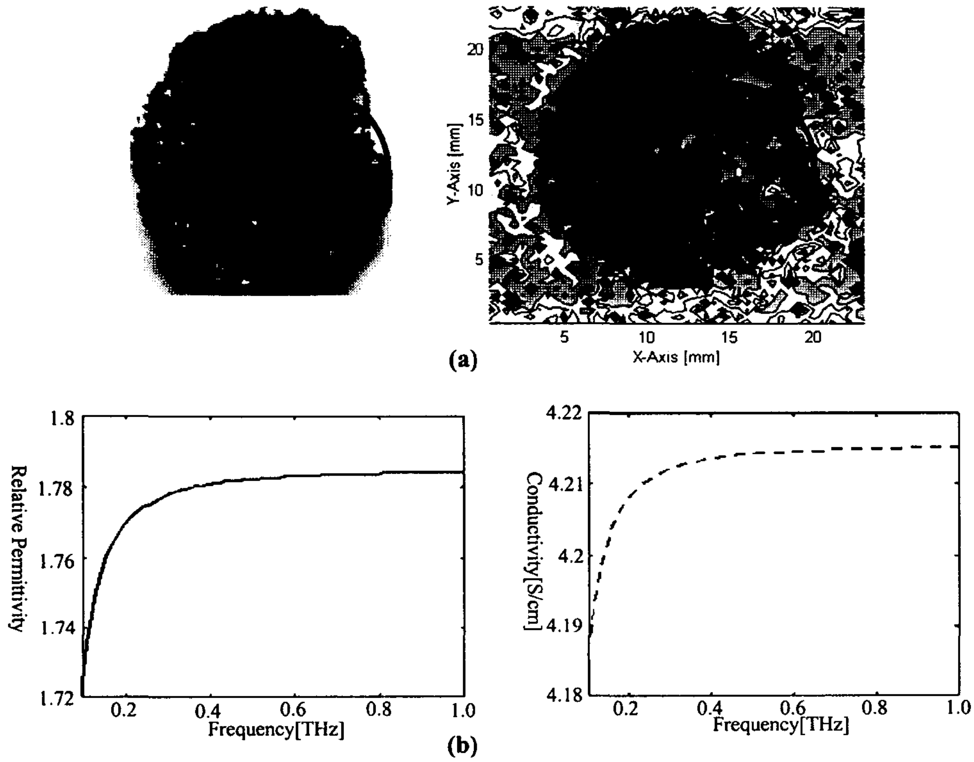

Fig. 2. (a) Cross-sectional terahertz image of the head part of the human rib for the diagnosis of osteoporosis. Photograph of the human rib is shown for comparison. (b) Extracted electrical parameters of a sliced bone.

4. Conclusions

We have successfully demonstrated the possibility of the terahertz imaging system for medical applications including the medical diagnosis for the dental cavity and the osteoporosis. Also high-frequency electrical parameters of the dentin and the bone were extracted using the terahertz time-domain measurement and followed genetic algorithm. More importantly, the terahertz imaging data are stored using digital forms, enabling the state-of-art data processing technique. Neural network algorithm were applied for improving the image quality and for reducing the noises. The spatial resolution of the images can be further improved by optimizing the teraherz beam optics and by improving the sensitivity of the photoconductive detectors. By further reducing the system size and costs, the proposed system can replace the part of current X-ray, ultrasonic or MRI systems for clinical diagnosis.