Forward-Nulling Passive Millimeter Wave Imaging Using Cooling Dielectric Tube

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Abstract—In order to improve the quality of object recognition characteristics in passive millimeter-wave (PMMW) imaging, a new method to form a null in the direction of human body and objects is proposed. The forward-nulling passive millimeter-wave imaging using a dielectric tube occupied by cooling water placed on focus line of a parabolic cylinder are performed. It is shown experimentally that the contrast between human body and conducting scatterers such as a conducting plate and a conducting sphere in the PMMW images is improved by the presence of cooling dielectric tube with parabolic cylinder.

I. Introduction

Imaging of concealed objects in clothes is accomplished in a noninvasive and noncontact manner by using passive millimeter-wave (PMMW) imaging techniques [1]. All substances radiate the thermal noise power proportional to the brightness temperature in MM-wave band. The imaging sensor array placed in a focal plane of lens receives, amplifies and detect the incoherent power of thermal noise radiated from the objects and forming the PMMW images corresponding to the brightness temperature distribution of object.

The contrast between human body and objects in the PMMW images depends on each brightness temperature and when two objects have almost the same brightness temperature with different intrinsic emissivity ϵ ($=1-r-t$, r: reflectivity, t: transmittance) and physical temperature, the difference becomes zero. In order to improve the contrast between them, a use of illumination of incoherent power to the human body is proposed [2].

In this paper, the forward-nulling passive millimeter-wave (FN-PMMW) imaging to form a null in the direction of human body and objects is proposed. A nulling source composed of a dielectric tube occupied by cooling water placed on focus line of a parabolic cylinder are developed.

II. Theory

Fig. 1 shows the lens system of the PMMW imaging device in a room surrounded by the wall. The imaging sensor array is located at the image plane $z = z_{im}$. Considering the case with no human body, the central imaging sensor located on a lens axis will observe brightness temperature distribution of the wall subtended by the lens with a solid angle of Ω_{L1}. When a human body stands at the object plane $z = z_{ob}$ taking a conducting plane with angle θ from the lens axis, the sensor will observe the wall in a solid angle of Ω_{L2}. When the temperature in the angle Ω_{L2} decreases by the presence of the large aperture incoherent source, the apparent temperature contrast between human body and the area of conducting plane becomes large. When the object is a conducting sphere, the sensor will observe the integrated power in Ω_{L2} and the integrated power of walls in Ω_e and human body, where $\Omega_e=4\pi - \Omega_{L2}$. When the difference between powers in Ω_{L2} and Ω_e becomes large, the apparent temperature contrast between human body and the conducting sphere becomes large.

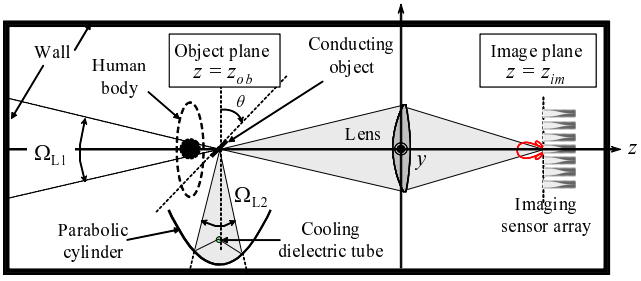

Fig. 1. Lens system in room (top view).

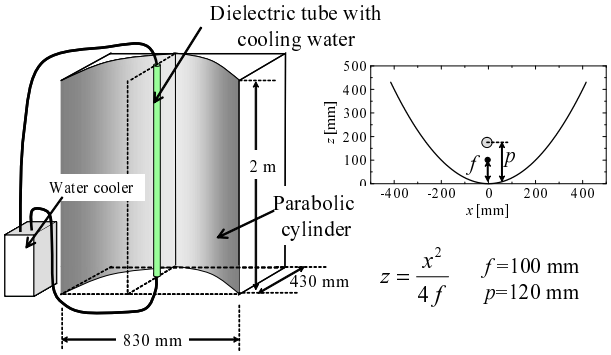

Fig. 2. Geometry of cooling tube with parabolic cylinder.

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III. Forward-Nulling PMMW imaging

The forward-nulling incoherent source with a dielectric tube occupied by cooling water and a conducting parabolic cylinder were developed as shown in Fig. 2. Dielectric tube is made of polyvinyl chloride and surface temperature of the tube is kept at 7.5 °C.

The parabolic cylinder is arranged as shown in Fig. 1 and the FN-PMMW imaging was performed using developed cooling dielectric tube with parabolic cylinder. Fig. 3 shows the PMMW images in the cases with and without cooling tube and parabolic cylinder when the circular conducting plate (CD-ROM) with radius of 60 mm is located in front of human body. The contrast between human body and CD-ROM was improved by the presence of cooling dielectric tube with parabolic cylinder. Fig. 4 shows the PMMW images and the distribution of received voltages along y axis when the conducting sphere with radius of 25 mm is located in front of human body. Improvement of the contrast between human body and conducting sphere was small compared with the case of CD-ROM, however, decrease of voltage were observed as shown in Fig. 4 (b) by the presence of cooling dielectric tube with parabolic cylinder and the validity of the theoretical study is confirmed.

IV. Conclusion

The FN-PMMW imaging using a dielectric cooling tube with a parabolic cylinder has been proposed and the improvement of the contrast between human body and the conducting objects in PMMW images has been obtained. The enlargement of nulling angle is a remaining subject.

ACKNOWLEDGEMENT

This work was supported by "Special Coordination Funds for Promoting Science and Technology" organized by Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

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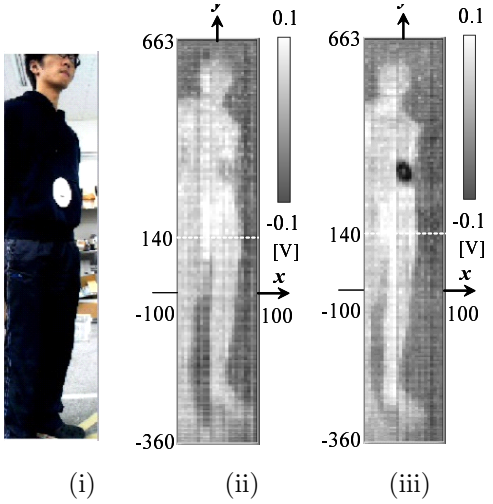
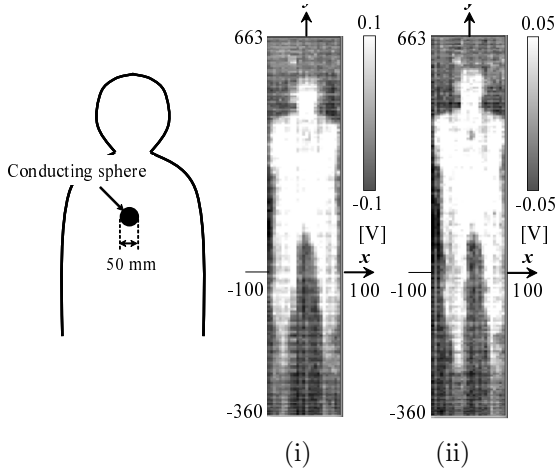
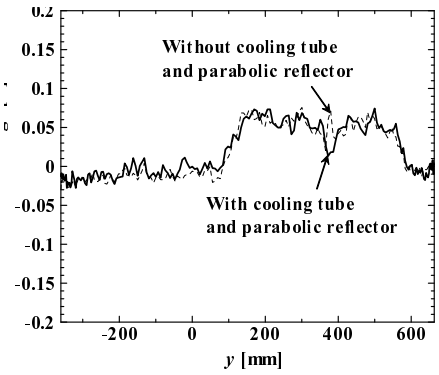


Fig. 3. Comparison of PMMW images between cases (ii) without and (iii) with cooling tube and parabolic cylinder (CD-ROM).



(a) PMMW images (i) without and (ii) with cooling tube and parabolic cylinder.



(b) Distribution of received voltage along y axis.

Fig. 4. Comparison of PMMW images between cases with and without cooling tube and parabolic cylinder. Object is conducting sphere with radius of 25 mm.