Forward-Nulling Passive Millimeter Wave Imaging Using Cooling Water-Wall

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***Abstract*—A cooling water-wall room is developed and the forward-nulling passive millimeter-wave (PMMW) imaging is performed using developed room. It is shown experimentally that high-quality of PMMW images is obtained by the presence of the cooling water-wall room which works as a nulling source and a shielding wall.**

I. INTRODUCTION

Passive millimeter-wave (PMMW) imaging technique [1] is expected as a method to detect concealed objects in clothes with non-invasive and non-contact manner and high detection performance of the PMMW imaging system is expected for the purpose of keeping safe and secure aircrafts, ships and train etc.

Considering the detection of scattering objects with high-reflectivity such as the conducting materials, the thermal noise radiated from the surrounding objects in a room such as walls, fluorescents, human bodies and electric devices, is scattered by the scattering objects and scattered conponents of thermal noise is received by the PMMW imaging devices. Then the PMMW imaging device images the scattering objects as the brightness temperature of apparent values. Therefore, the contrast of the high-reflectivity object depends on a surrounding temperature environment and the contrast becomes lower as the physical temperature of surrounding objects in a room increases.

In our previous works, the forward-nulling PMMW imaging method forwarding a null in the direction of human body and objects was proposed and some nulling sources using cooling dielectric tubes and parabolic cylinder were developed so far [2, 3].

In this paper, the cooling water-wall room is developed as a practical nulling source and the forward-nulling passive millimeter-wave (PMMW) imaging is performed to improve the detection performance of a PMMW imaging systems [4, 5].

II. THEORY

Let us consider the PMMW imaging in an indoor environment surrounded by the walls as shown in Fig. 1 (a). A human body with a conducting plate stands in front of a PMMW imaging device composed of a lens and an imaging sensor array. Assuming the reflectivity of the wall is small,

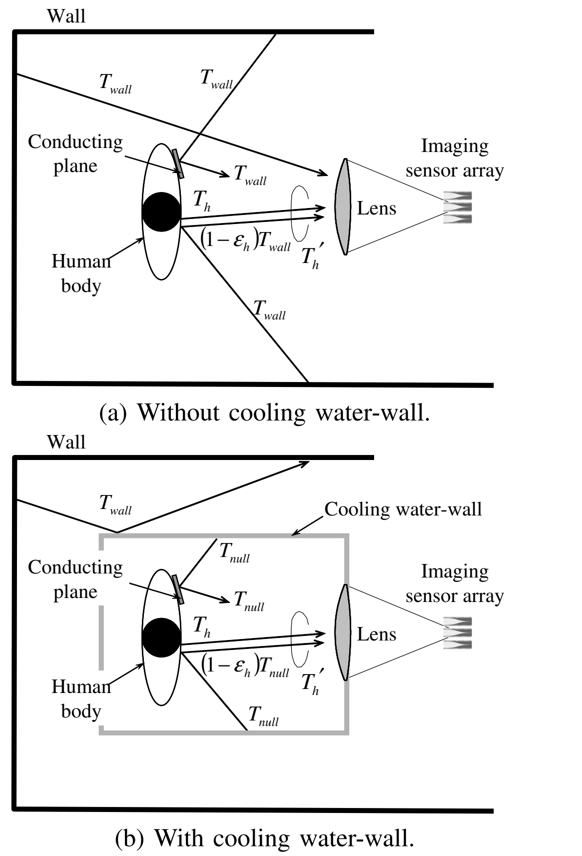

Fig. 1. Lens system in room (top view). (a) Without cooling water-wall, (b) With cooling water-wall.

the apparent temperature of a human body T_h' is given by

$$T_h' = T_h + (1 - \varepsilon_h)\, T_{wall} \tag{1}$$

where ε_h is the emissivity of a human body and T_h, T_{wall} are the brightness temperatures of a human body and the surrounding wall, respectively. Assuming the reflectivity of the conducting plate to be unity, the PMMW imaging device observes the brightness temperature of the wall in a region of the conducting plate as a reflector and the apparent temperature of the conducting plate is given by T_{wall}. Therefore, the apparent temperature difference $\Delta T_c'$ between a human body

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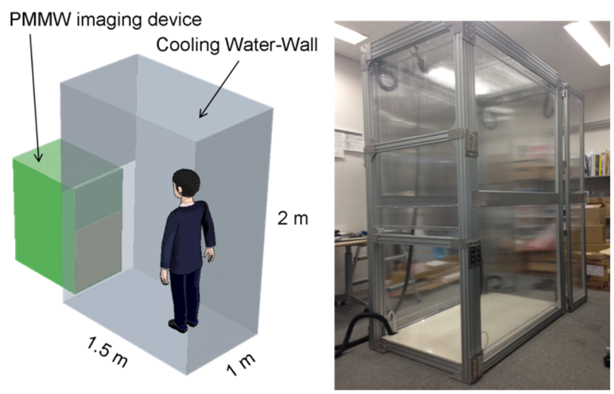

Fig. 2. Geometry of cooling water-wall.

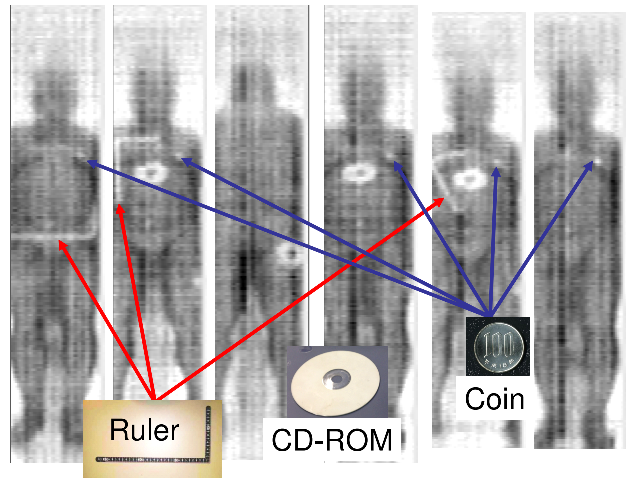

Fig. 3. PMMW images when human body with conducting plates is placed in developed cooling water-wall room.

and a conducting plate is given by

$$\Delta T'_c = T_h - \varepsilon_h T_{wall}. \tag{2}$$

When an incoherent cooling water-wall as a nulling source with the brightness temperature T_{null} is enclosed as shown in Fig. 1 (b) so as to block the thermal noise produced by the wall, the apparent temperature difference between a human body and a conducting plate $\Delta T'_{null}$ is given by

$$\Delta T'_{null} = T_h - \varepsilon_h T_{null} \tag{3}$$

and the PMMW image with higher contrast $\Delta T'_{null} > \Delta T'_c$ is obtained when $T_{null} < T_{wall}$.

III. Geometry of Cooling Water-Wall

Geometry of developed cooling water-wall room is shown in Fig. 2. A cooling water-wall room with dimensions of 1.5 m(D)×1 m(W)×2(H) are placed in front of a 77 GHz PMMW imaging device [4, 5] and the human body is placed in the room. In order to fix water with a planar geometry and to compose the water-wall, a commercial dielectric panel composed of 2-layer dielectric sheet made of thin Polycarbonate (Twin-carbo, manufactured by Asahi Glass Co. Ltd.) are utilized. Thickness of water-wall is 4 mm and 6 water-wall are installed by frames made of aluminum. Input-output ports of water are fabricated at the edge of each water-wall and water branch circuit are also fabricated to equalize the temperature of 6 water-wall. Cooling water with temperature of 3 °C is circulated using the cooling water device and average surface temperature is kept at 12 °C when room temperature is 20 °C.

IV. PMMW imaging

Fig. 3 shows the PMMW images when a human body with conducting plates is placed in the developed cooling water-wall room. A circular conducting plate (CD-ROM) with radius of 60 mm, a circular conducting plate (coin) with radius of 12 mm and a ruler with the width of 15 mm are placed on the surface of a human body. High-contrast between human body and conducting plates is observed. It is considered that the front water-wall works as the nulling source to decrease the brightness temperature of conducting plate and the other water-walls work as shielding walls to block the thermal noise from surrounding walls.

V. Conclusion

The cooling water-wall room has been developed to increase detection performance of the forward-nulling PMMW imaging. A high-contrast PMMW image of conducting plates has been performed and high quality of PMMW images has been obtained.

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