Incoherent Active Millimeter-Wave Imaging Using Forward-Illuminating Source

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***Abstract*— In this paper, the forward illuminating source is applied to the passive millimeter-wave (PMMW) imaging technique in order to improve contrast between the objects and human body. Imaging data for the cases of several material are compared with changing the geometry of materials. As a result, the relation is clarified between the imaging data and the analytic reflectivity, emissivity and transmittance.**

I. Introduction

Some materials of liquid, plastics and powder can be ingredients for explosives, and subversive activities such as terrorism have been brought by using handmade bomb made of such dielectric materials. It is easy to hide them in clothes and development of detection system for concealed artifacts is strongly desired for the purpose of keeping safe and secure aircrafts, ships and train etc.

Imaging of concealed objects in clothes is possible in a noninvasive and noncontact manner by using the passive millimeter-wave (PMMW) imaging techniques [1]. All substances radiate the thermal noise. Power of the thermal noise is proportional to the brightness temperature in millimeter-wave band. PMMW imaging device is composed of a lens, the imaging sensor array placed in the image plane and a signal/image processing system which forms the PMMW images.

Considering the detection of scattering objects with high reflectivity such as the conducting material, the thermal noise radiated from the surrounding objects in a room such as the walls, the fluorescents, the human bodies and the electric devices, incident to the objects in clothes and reflected by them. Then the PMMW imaging device images the scattering objects as the brightness temperature of apparent values. Therefore, the contrast depends on a surrounding temperature environment and the contrast becomes lower as the physical temperature of surrounding objects in a room increase.

In order to overcome this problem, the effect of illumination to a human body and objects to increase the contrast of PMMW imaging were investigated [2, 3].

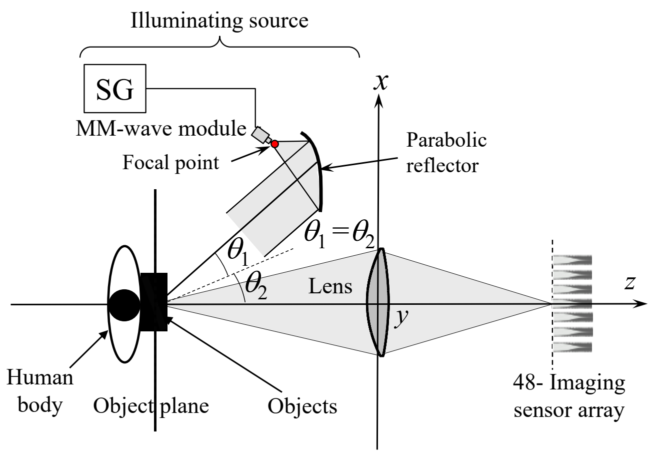


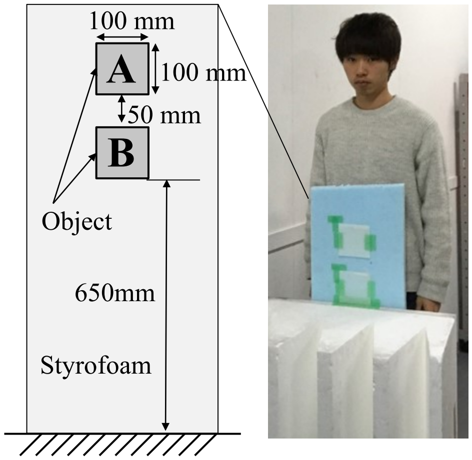
Fig. 1 Optical system of Sub-Active imaging.

Also the received power with different geometry and various type of materials were evaluated and were compared with the analytic reflectivity, emissivity, transmittance.

II. Optical System with Illuminating Source

77 GHz-band PMMW imaging device developed in [1] was used for the experiment. Figure 1 shows the simplified optical system of PMMW imaging device and arrangement of other equipment. PMMW imaging device is composed of a dielectric lens with diameter of 500 mm and one-dimensional imaging sensor array of 48-elements located at the image plane. Also a flapping reflector synchronized to the signal/image processing have been employed to obtain 2-dimmensional images by using one-dimensional 48array elements.

A human body stands at the object plane. Two plate objects fixed by a Styrofoam are located in front of the human body. A parabolic reflector with a focal length of almost f=200 mm were used as an illuminating source. A millimeter wave source module with an aperture of



Case	Region A	Region B
1	Conductor 1 mm	Conductor 1 mm
2	Polyethylene 1mm	Polyethylene 2mm
3	Ceramic 1mm	Ceramic 2mm

Fig. 2 Arrangement and combination of objects.

WR-12 waveguide was used as an illuminating source and is located at the focal point of parabolic reflector. The frequency was 77 GHz and incident power was set as -4 dBm.

III. IMAGING RESULTS

The arrangement and the combination of objects are shown in Figure 2. The objects of rectangular plate have the height of 10cm and the width of 10cm and the thickness of 1 mm or 2 mm. Materials of the conductor, the polyethylene and the ceramic were used. Positions of two objects were indicated as A and B except for the case of conductor.

Figure 3 shows the distribution of received voltages of an imaging sensor along y-axis in the case with and without the illuminating source. Case 1, 2 and 3 in Fig. 3 are the cases when the material of objects are conductor, polyethylene and Ceramic, respectively. High contrast between human body and objects for three cases were observed due to illuminating source.

In the case of conductor (Case 1), two peaks of received voltages were observed at 69 pixel and 79 pixel with almost same voltages of 4.4 V, respectively, which means that the illuminating source excites two conductors with almost uniform field distribution.

In the case of polyethylene (Case 2), received voltages of 0.6 V at A (1 mm) and 1.4 V at B (2 mm) were observed, respectively. These results show that the reflection from 2 mm case is larger than 1 mm case and the thicker polyethylene has a large reflectivity.

In the case of ceramic (Case 3), received voltages of 2.9 V at A (1 mm) and 1.5 V at B (2 mm) were observed, respectively. These results show that the reflection from 1 mm case is larger than 2 mm case and the thicker ceramic has a small reflectivity.

In order to explain above results, plane wave exact analysis were performed and was compared with the received voltages obtained by the experiments. Figure 4 and Figure 5 show the reflectivity, the transmittance and the emissivity as a function of the thickness of plate objects, for the cases of polyethylene and ceramic, respectively. 3-layer slab with the relative permittivity and the loss tangent shown in each figures were used for plane wave analysis.

In the case of polyethylene, quite large transmittance was observed. Also it was observed that the reflectivity of 2 mm thickness is larger than that of 1 mm thickness. On the other hand, in the case of ceramic, strong dependence to the thickness was observed. Also it was observed that the reflectivity of 2 mm thickness is smaller than that of 1 mm thickness. From the above results, it can be concluded that the received voltages obtained by the sub-active imaging has a correlations to the reflectivity of plane wave analysis in the case of plane objects.

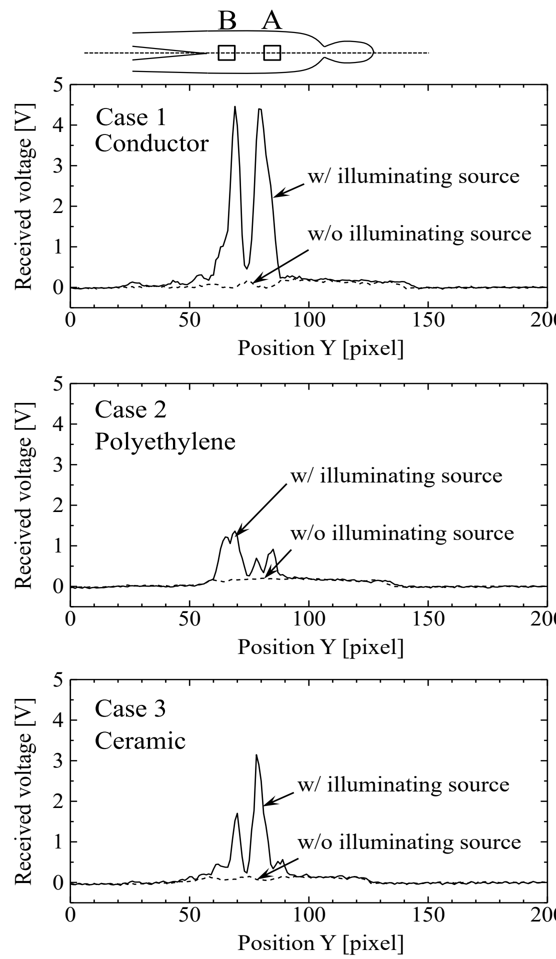


Fig. 3 Received voltages with and without illuminating source.

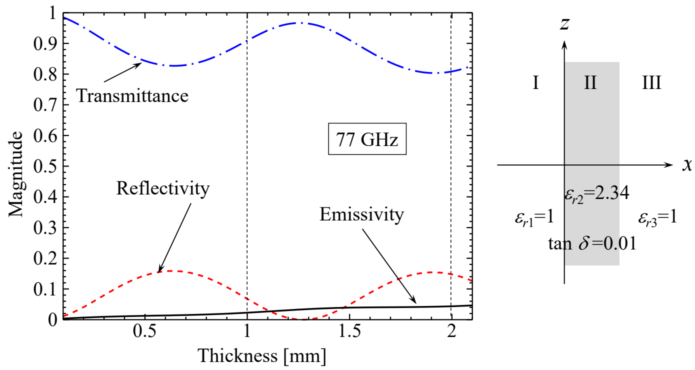


Fig. 4 Reflectivity, transmittance and emissivity as a function of the thickness of polyethylene.

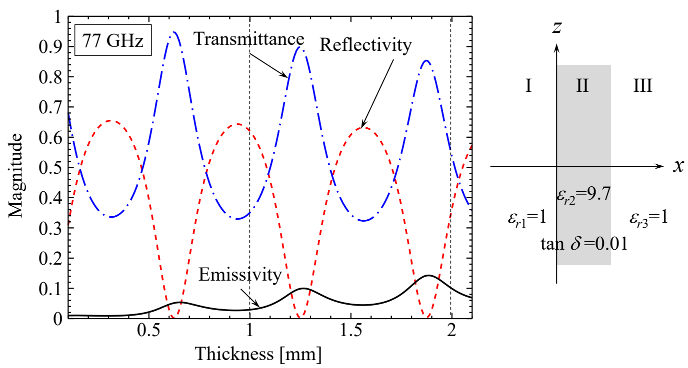


Fig. 5 Reflectivity, transmittance and emissivity as a function of the thickness of ceramic.

IV. Conclusions

In order to improve the contrast between human body and objects, we applied forward illuminating source to PMMW imaging technique. Received voltages for the cases of several material are compared with changing the thickness of each materials. High contrast between human body and objects for three cases were observed by the presence of the illuminating source. It can be concluded that the received voltages obtained by the sub-active imaging has a correlation to the reflectivity of plane wave analysis in the case of plane objects.

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References

[1] H. Sato, K. Sawaya, K. Mizuno, J. uemura, M. Takeda, J. Takahashi, K. Yamada, K. Morichika, T. Hasegawa, H. Hirai, H. Niikura, T. Matsuzaki, J. Nakada, “Development of passive millimeter wave imaging device using 77GHz Band (Invited)”, Proc. IEEE SENSOR 2009, pp.1632-1635, Oct. 2009.

[2] P. Goldsmith, C. T. Hsieh, G. Hugnenin, I. Kapiuky, and E. Moore, “Focal plane imaging systems for millimeter wavelengths”, IEEE Trans. on Microwave Theory and Techniques, vol. 41, no. 10, pp.1664-1675, Oct 1993.

[3] H. Sato, K. Kuriyama and K. Sawaya, "Forward-Nulling Passive Millimeter Wave Imaging Using Cooling Dielectric Tube," IEICE Trans. Commun., vol. E95-C, no. 10, pp. 1627-1634, 2012.