

学 位 論 文 の 要 旨

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学位論文題目 : Study on Dielectric Lens-Based Millimeter-Wave Imaging System for Security Application (英訳又は和訳 誘電体レンズを用いたセキュリティ用途向けミリ波イメージングシステムの研究)			
<p>The increasing security threats in public space have increased the need for security screening systems to detect hidden objects. Traditional security and surveillance techniques have limited utility in practical applications. Metal detectors are limited to detecting metal objects and cannot identify modern plastic-based threats. X-ray scanners pose a high radiation risk and are primarily used to inspect personal belongings. Surveillance cameras cannot detect concealed objects, such as knives or firearms, under a person's clothing. These traditional techniques are usually integrated into security screening systems in public space and rely on manual detection techniques, increasing waiting times and reducing security screening efficiency. Consequently, there is a challenge in developing sensing technologies that can quickly and safely screen large numbers of people without disrupting the flow.</p> <p>Millimeter-wave (mmW) radiation is gaining increasing attention due to its high spatial resolution and safe penetration through clothing to serve as a remote sensing and security screening system. To improve throughput operation with a reasonable resolution through non-contact screening, this study investigates the development of an mmW radio-imaging system utilizing a dielectric lens that improves the focusing of mmW signals, magnification of the target area, support of a wide frequency range, and enables Fourier transformations.</p> <p>In this thesis, a dielectric lens-based millimeter-wave imaging system for security application is discussed. Analysis and experimental findings regarding using dielectric lens in imaging systems using W-band (75-110 GHz) mmW signals are presented. With the help of the dielectric lens, the reflected signal from the target is focused and enhanced, effectively increasing the system's receiving signal and observation distance. Through the strategic use of the lens, signal amplitudes and phases are effectively measured, yielding an image reconstruction of objects concealed by a layer of paper or clothing. Moreover, dielectric lens allow for a relatively wide range of frequencies. Therefore, by utilizing an mmW frequency sweep operation, it becomes possible to obtain depth information and facilitate generating a three-dimensional (3D) image of the target.</p> <p>This thesis is organized as follows:</p> <p>Firstly, an overview of the increased security concerns in public space, and the need for improving remote inspection is provided. It then outlines the limitations of existing security screening technologies and introduces mmW imaging using dielectric lens as promising method for security assessment. This will lay the groundwork for the challenges and objectives of the thesis.</p>			

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Secondly, a comprehensive explanation of the theoretical backgrounds involved with mmW imaging using dielectric lens is provided; it forms the basis of this research. The section covers the principles of mmW imaging, from diffraction and wave propagation principles via the lens, and describes how dielectric lens facilitate imaging in mmW imaging systems. A theoretical framework is given from which further simulations and experiments about this imaging approach could be set forth.

Thirdly, a simulation analysis is performed to forecast the optimal configuration for the experiment. In this respect, simulations of different configurations, like shape variations of objects and frequencies, make the outcome of this analysis a valuable indication to follow while performing experimental investigations.

Fourthly, the experiment focuses on utilizing a dielectric lens for mmW imaging is presented. These experiments demonstrate successful reconstructions of objects in 2D using a single frequency. Concealed scenarios are also investigated to evaluate the imaging system's capability to detect hidden objects.

Fifthly, it extends the approach introduced in the previous chapter towards 3D imaging using wideband operation frequency. The experimental results indicate the successful reconstruction of objects in a 3D space and show the system's efficiency in shape and depth identification by applying mmW frequency sweep operations, especially in scenarios where objects are hidden.

Overall, this thesis contributes to mmW imaging methodology to the security concern and innovatively presents an imaging system approach that makes it possible to detect and generate reconstructed objects effectively, enhancing non-contacting security measures. The groundwork laid concerning mmW imaging and security applications, therefore, through current shortcomings, will provide a way for development using rigorous research and experimentation. These results then identified several possible opportunities for further improvements in security screening systems for hidden objects and the safety of people in public spaces.