

## Development of a Millimeter-Wave Shoe Scanner System

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US airline passengers are currently required to divest outer layers of clothing before they pass through TSA security checkpoints. Clothing divestment, especially shoes, is a significant impediment to efficient screening. Reduced throughput in security checkpoints increases inconvenience to passengers, which ultimately leads to lost revenue for airports and lost productivity for the general economy. Therefore, a need exists for a technical approach to accomplish comprehensive passenger-worn footwear screening

The Pacific Northwest National Laboratory (PNNL) was funded by the Department of Homeland Security (DHS) Science and Technology (S&T) Directorate to develop and deliver a refined engineering prototype millimeter-wave (mm-wave) footwear screening system. This system would detect concealed threats in person-worn footwear by providing detailed three-dimensional radar images of the footwear interior volume suitable for threat detection algorithms. The underlying technology is the same as that currently employed in mm-wave AIT portals developed at PNNL and used in airports for the detection of body-worn threats.

An initial laboratory prototype shoe scanner system was quickly developed for use at PNNL to collect mm-wave imagery using mock passengers with a variety of footwear types and sizes. This prototype system consists of several subsystems including a 10-40 GHz switched 120-element antenna array and transceiver. This initial system, shown in Fig. 1, was designed with maximum flexibility to evaluate various array scanning configurations and optimize image reconstruction algorithms to aid in development of the deliverable engineering prototype system. The laboratory prototype system rapidly collects data which enables an extensive investigation of different screening scenarios with minimal operator time required.

This presentation will provide an overview of the design and implementation of the mm-wave imaging shoe scanner laboratory prototype system. The presentation will also include example images for different footwear scanning configurations. Technical hurdles regarding penetration through heterogeneous dielectric media as well as achieving fine lateral and range resolution in the person-worn footwear environment were addressed through the implementation of a high-frequency and wide bandwidth system. The use of wide bandwidth and mm-wave frequencies was also shown to improve the system's lateral and range resolution. Additionally, the inclusion of frequencies between 10 GHz and 20 GHz was determined to facilitate sufficient signal penetration through the selected dielectric layers and footwear types.



Figure 1. (left) PNNL mm-wave shoe scanner laboratory prototype system, (center) scan of mock passenger wearing sneakers, (right) example mm-wave imagery revealing F-target located inside shoe.