Switched Antenna Array Tile for Real-Time Microwave Imaging Aperture

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***Abstract*—A switched array tile which is part of a large aperture for near-field microwave imaging is presented. The tile is based on the Boundary Array (BA), a sparse array topology for hardware efficient realization of imaging apertures. The larger array formed with the tile samples a scene with no redundancy, and is compatible with fast imaging techniques. Details on the design and realization of the tile are presented, as well as experimental images formed with a tile prototype.**

I. Introduction

In recent years, microwave imaging has emerged as a valuable tool for concealed weapons detection [1]. While this modality has been widely deployed in checkpoint scenarios, a need exists for a system that can monitor high foot traffic environments (e.g., mass transit systems, stadiums, public events). To this end, the system notionally depicted in Fig. 1 is currently under development at MIT Lincoln Laboratory. One critical aspect of this system is the switched array used to sample the scene. This paper discusses realization of a sub-aperture or "tile" of that array. In the next section, the design of the array and tile are discussed, while initial imaging results are presented in Section III.

II. Array Design and Tile Construction

The switched array tile depicted in Fig. 1 is the elementary unit of the aperture depicted in the notional diagram of the system. The tile is based on the Boundary Array (BA) [2] where two linear transmit arrays are used (one on each side of the tile) and two linear receive arrays are used (one of top, one on bottom). Activation of a single transmit element and a single receive element forms an effective phase center. As depicted in Fig. 1, if every possible transmit-receive combination is considered, then a regularly spaced grid of phase centers is formed.

The full switched array depicted in Fig. 1 is a 6x6 arrangement of the switched tile (where, in some cases, linear arrays are shared between adjacent tiles). Sampling occurs only within each tile: that is, no linear transmit array communicates with a non-adjacent receive array. The effect is that the scene is sampled on a regularly spaced grid of phase centers that covers the aperture. This allows for use of the fast imaging technique presented in [3], a key difference between this design and the one presented in [4] where the boundary array was used in a slightly different arrangement.

As noted, the tile contains two linear transmit arrays and two linear receive arrays. Each array set is a pair of mirror images,

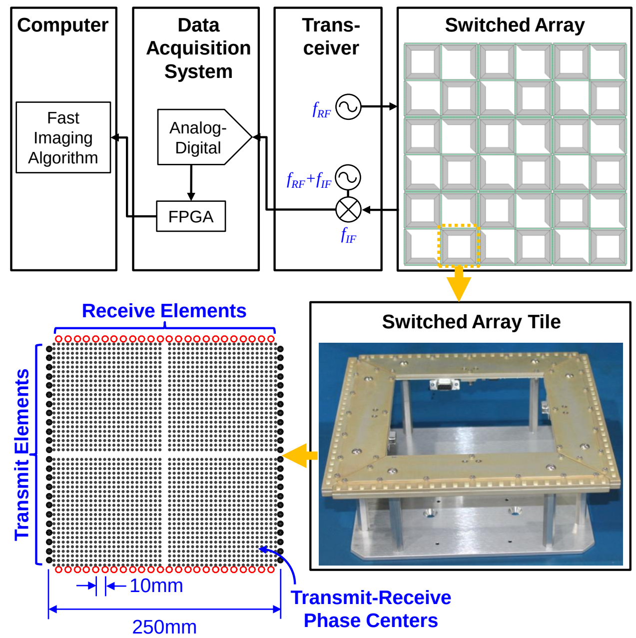

Fig. 1. Diagram of real-time imaging array, with fabricated antenna tile.

except for antenna antenna layout, which varies to ensure that all arrays use the same polarization. Fig. 2 depicts one of the receive arrays with and without its metal housing. As seen, the array employs 11 SP4T switches, which is used to create a 24-way switch for the antenna elements. Buried striplines are used to connect the switches and antennas, minimizing the potential for crosstalk with transmit arrays. Additionally, the receive arrays use 6 LNAs, behind the first row of SP4T switches. The transmit arrays use a similar layout, except that they use only a single amplifier at the input of the entire 24-way switch.

Control of the switched elements is accomplished through the use of a CPLD (Complex Programmable Logic Device), which is depicted in 3. The CPLD simply stores switch biases for the array's 24 switch states, which can be toggled sequentially by sending a pulse to the u.fl connector labeled "Element Step." The state list is reset by pulsing the labeled "Reset" input. This control scheme is not only simple, but also is independent of acquisition speed.

The arrays use the slot antenna element depicted in Fig. 4. The element is integrated within the array's aluminum

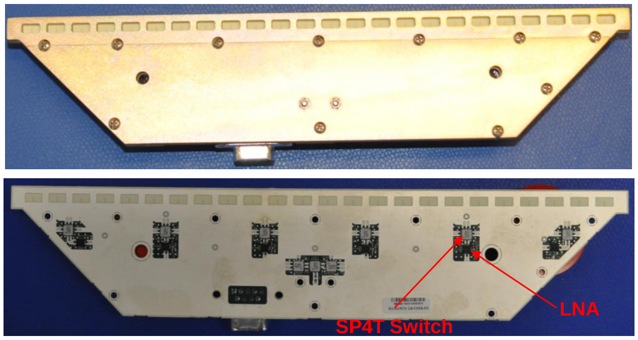

Fig. 2. Radiating side of linear receive antenna array with and without aluminum housing.

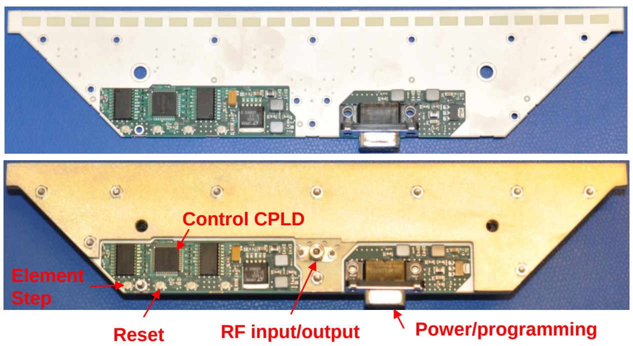

Fig. 3. Non-radiating side of linear receive antenna array with and without aluminum housing.

housings, where the radiating slot is etched in the upper housing, and a cavity backing is etched in the lower housing. As seen in the simulated pattern plot of Fig. 4, the simple design provides a broad pattern in both E- and H-planes.

III. Imaging Results

To assess the imaging capability of a fully electronic tiled aperture of the array depicted in Fig. 1, the single tile was placed on an x-y scanner as seen in. The tile was mated with a 4-port Vector Network Analyzer (VNA). The scanner was used to move the tile to an arrangement of 5x5 positions, covering 1.25m. At each position, all transmit-receive antenna combinations were used to sample the frequency response of the scene from 21-26 GHz. This samples the scene in the same manner that a full 1.25m aperture would. A scene containing only a metalized mannequin was imaged using the setup. Using the image reconstruction scheme described in [3], the microwave image depicted in Fig. 5 was formed.

IV. Conclusions

A switched array tile to be used in a real time imaging aperture has been presented. Design and realization of the tile were described in detail. Initial imaging results show that the tile is suitable for near-field imaging, and is compatible with fast imaging techniques.

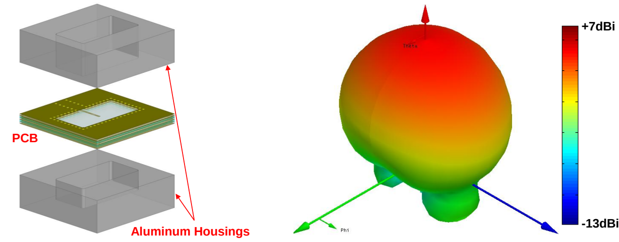

Fig. 4. Antenna array element with simulated realized gain pattern at 26 GHz.

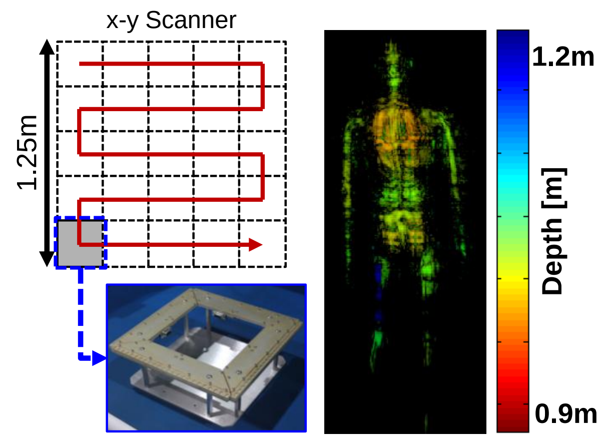

Fig. 5. Setup for imaging experiment emulating 1.25m aperture and resultant image at 21-26 GHz.

Acknowledgement

The authors thank Daniel Baumgartner and David Bragdon for board layout and design support. Additionally, the authors thank Ed Martin and Birol Bekirov for assistance with measurements.

This work is sponsored by the Department of Homeland Security, Science and Technology Directorate under Air Force Contract #FA8721-05-C-0002. Opinions, interpretations, recommendations and conclusions are those of the authors and are not necessarily endorsed by the United States Government.

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