MIMO SENSOR ARRAY FOR SHORT-RANGE, HIGH-RESOLUTION AUTOMOTIVE SENSING

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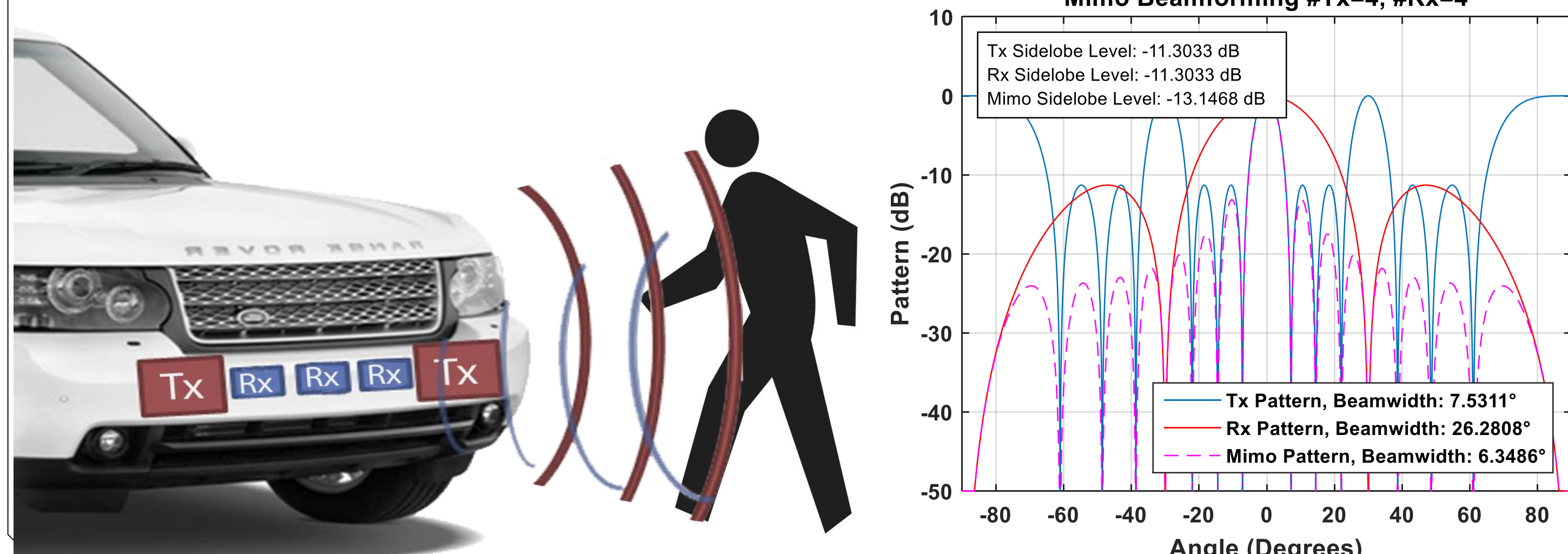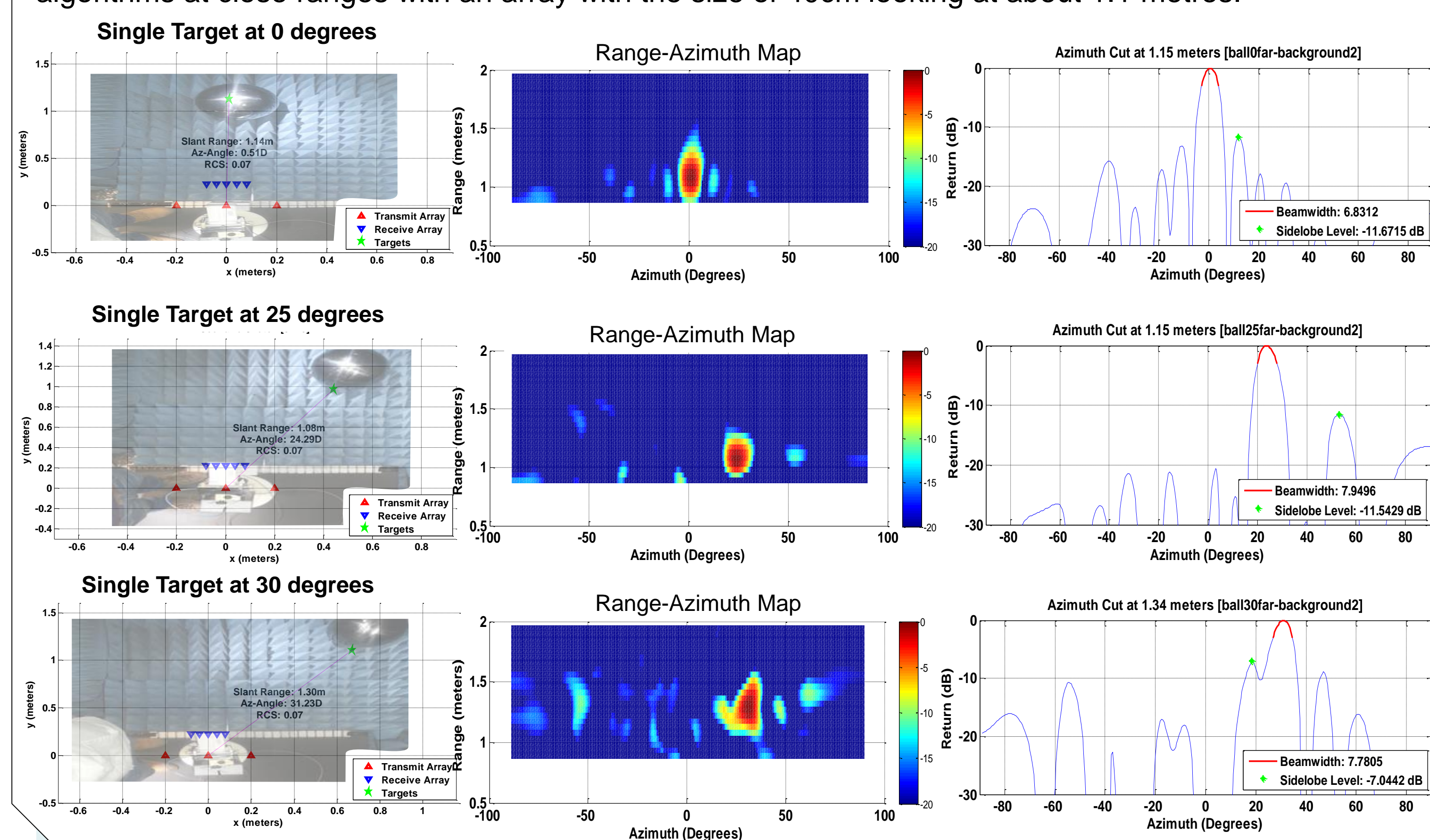
1. Introduction

The aim of the project is to investigate a novel Multiple-Input-Multiple-Output (MIMO) sensor system for automotive applications. Compared to traditional phased arrays, a MIMO array can achieve the same fine angular resolution, but with a drastically reduced amount of sensor elements. A MIMO array of 8 elements can deliver the same resolution as a phased array of 16 elements. The other highlight of this technology is that it can operate at short ranges, which is physically impossible with a phased array as the beam requires significant distance from the antenna aperture to form. Therefore a MIMO system can potentially provide very high angular resolution at short ranges. These properties make such a system attractive for a number of automotive applications, including parking aids, short-range cruise control, speed-over-ground estimation, pedestrian and object detection and collision detection.

2. Phased vs. MIMO Array

A phased-array-antenna radar can be used with beam-forming techniques to direct a beam to a specific location. And then the radar can scan the desired area electronically. This can be achieved since, the correlated signals from transmit antennas would add up constructively or destructively in different directions in space. On the other hand, a MIMO radar uses the advantage of orthogonality for various advantages. These advantages can be; reduced amount of necessary array elements, increased angular resolution, faster scan time, simultaneous search & track etc. With a MIMO array; beamforming process does not have to happen in the space but in the digital space, so we can "illuminate" the whole space of interest with single transmission.
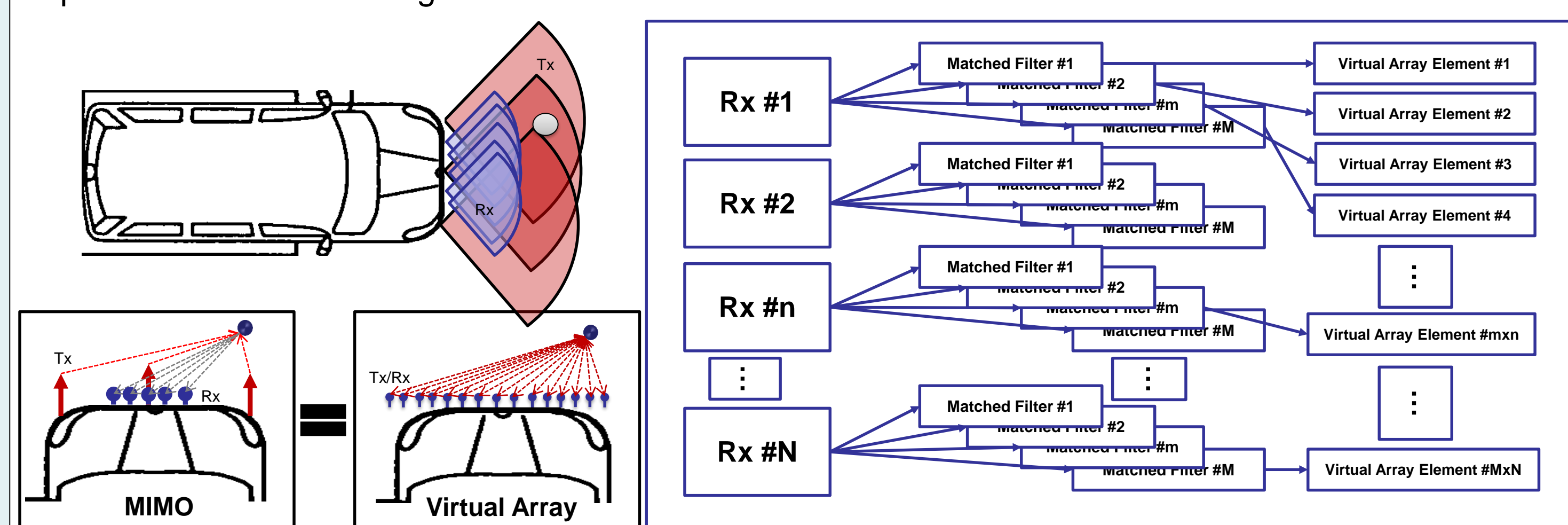
- Matched filtered signals can be interpreted as the signals out of the virtual array elements.
- Virtual Array Concept: M+N MIMO elements give the same angular resolution of MxN phased array
- Drastic reduction in antenna elements
- Example: 4+4 MIMO = 4x4 Phased Array
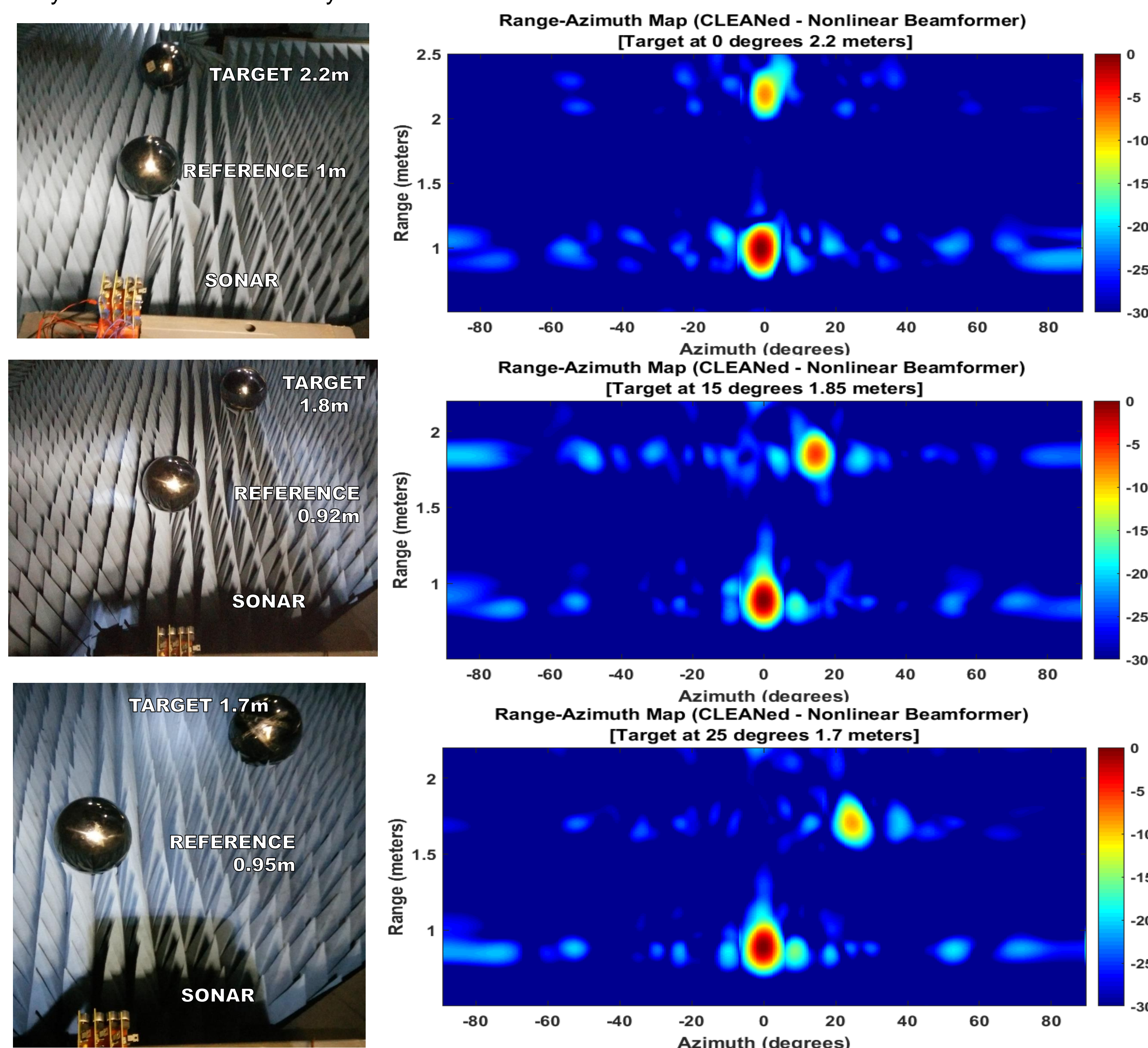- Cheaper and more diverse system

3. Nearfield MIMO

Nearfield MIMO techniques can be used for scanning areas without losing focus in close ranges with a tradeoff with more computation. The solution uses an actual geometric model rather than a far-field approximated model to derive the array factor. Below are our experimental results from our nearfield algorithms at close ranges with an array with the size of 40cm looking at about 1.1 metres.

4. Aperiodic MIMO

To further optimize the MIMO arrays, we looked into thinned arrays. Since MIMO array patterns are obtained from their equivalent virtual arrays, optimizing MIMO array patterns is not a straightforward job. To achieve this task, we utilized various optimization algorithms to find solutions; namely random descent, simulated annealing and genetic algorithm. Our specialized implementations of these algorithms have successfully yielded us practical solutions. Below is a comparison of a conventional MIMO array and one of our Aperiodic MIMO arrays.

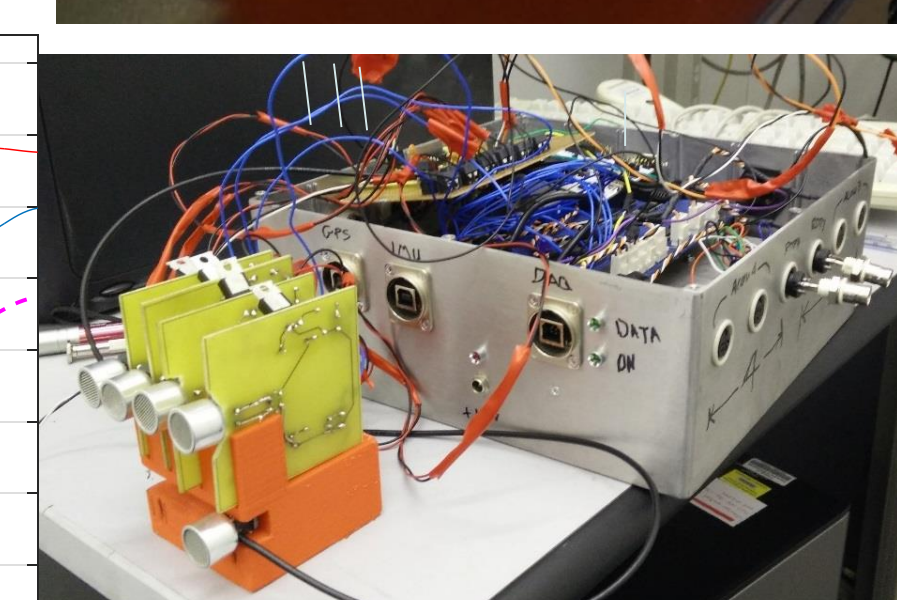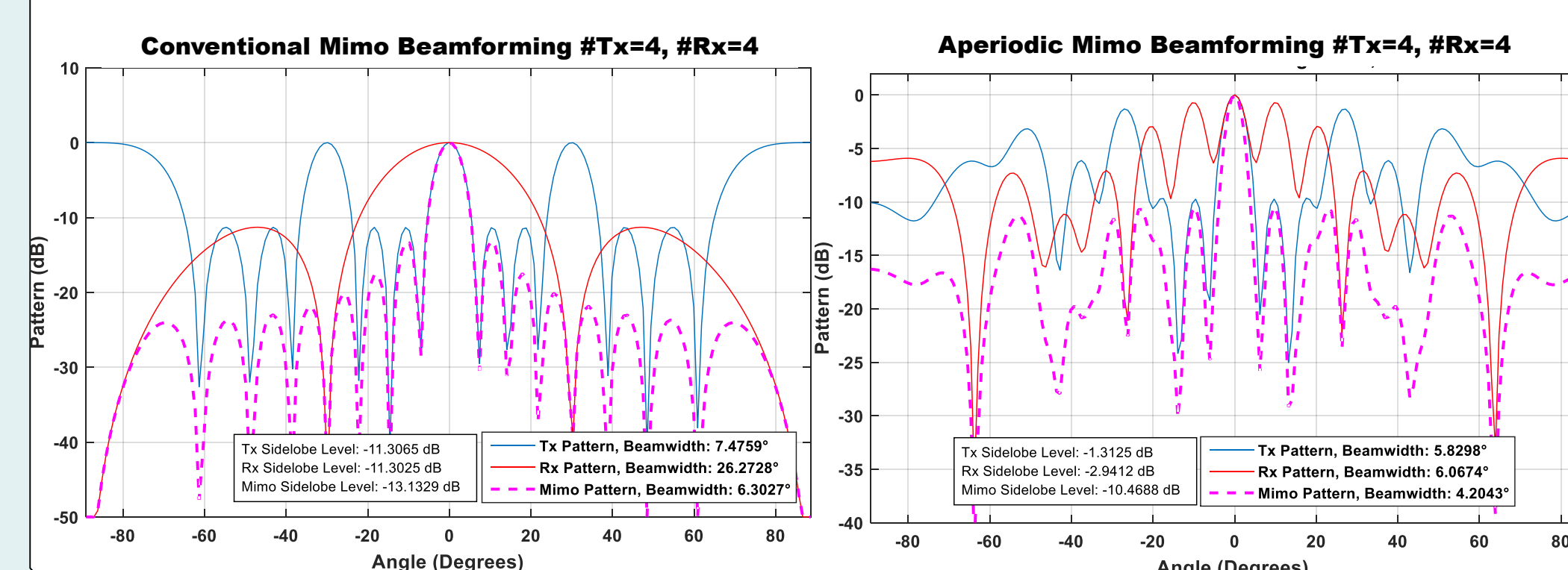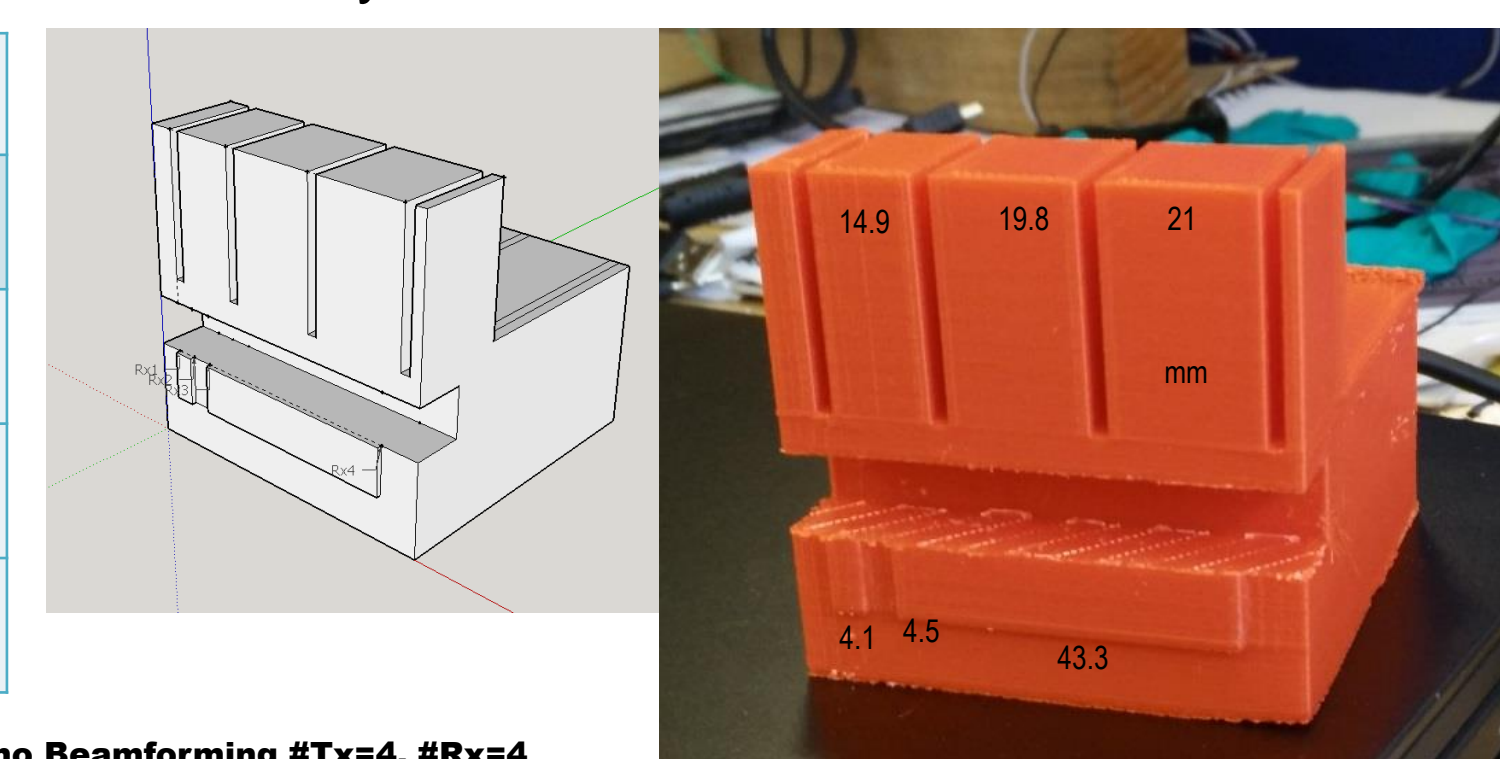| (Scanning 0 degrees)	# of Elements	Beamwidth	Sidelobe Level	Equivalent PA Elements
Conventional MIMO (sim)	8 (4+4)	6.30	-13.1 dB	16
Conventional MIMO (exp)	8 (4+4)	6.48	-12.9 dB	16
Aperiodic MIMO (sim)	8 (4+4)	4.20 (~65%)	-10.5 dB	24
Aperiodic MIMO (exp)	8 (4+4)	4.25 (~65%)	-7.3 dB	24

5. Experimental Results with Calibrated Targets

Less reflective targets may disguise as range/angular sidelobes, or angular/range sidelobes may add up to create fake targets. To overcome these problems CLEAN was modified for our purposes, which is mainly used in radio astronomy.

6. Experimental Results with a Bicycle

Finally experiments were performed using non-calibrated real life targets such as a bicycle. Below is a range-angle map superimposed on an optical image and post-processed with CLEAN algorithm based on absolute values of the returns.
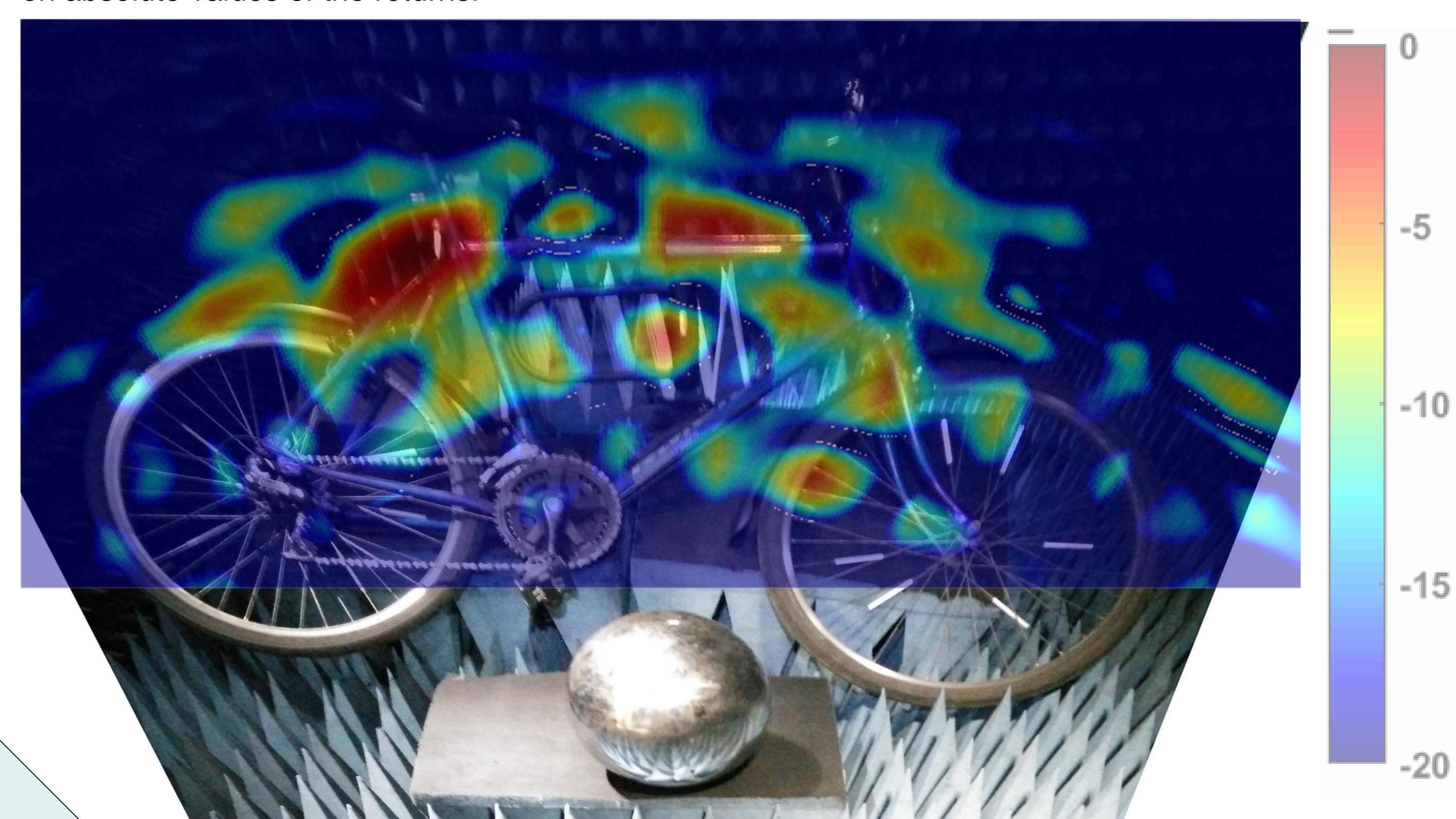
7. Conclusions & Future Work

Conclusions:
- MIMO concept applied to automotive context
- Obtained further performance improvements
- Produced acoustic technology demonstrator, tested and verified
- Technology is not limited to sonar, can be moved into RF domain (e.g. for higher maximum range)

Future Work:
- Replacing receivers with miniature SMD components
- To have a fully functional "plug and play" prototype