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A velocity independent continuous tracking radar concept

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ABSTRACT

This paper presents a novel concept for tracking a moving object with a radar system through all phases of the object's motion. The concept involves gathering and processing the raw radar data into various products at video rates. The various products are "tuned" to the different velocity ranges of the object. These various products are then fed into the tracking algorithms and the radar is guided to maintain illumination of the object at all times. The authors will present preliminary results from data collected with the Sandia National Laboratories' Ka-band radar system.

Keywords: radar, velocity tracking radar, ground moving target indication, synthetic aperture radar, video synthetic aperture radar, tracking algorithms, tagging/tracking/locating systems, intelligence/surveillance/reconnaissance systems, Ka-band radar

1. INTRODUCTION

Tagging, tracking, and locating (TTL) and intelligence, surveillance, and reconnaissance (ISR) systems have missions to identify a target of interest, track it, and determine its locations. Each one of these tasks in the mission has its own set of complexities and difficulties that must be overcome for the overall mission to be successful. When the chosen target has a motion component associated with it, the task of continuously tracking the target becomes more difficult. The sensor used to observe and track the target must have the ability to follow the target through different motion, i.e. velocity, states.

This paper presents a technique for tracking a target through all states of its motion using a radar system. It utilizes two radar products to track the target. The first product is a ground moving target indicator (GMTI) image while the second product encompasses Video Synthetic Aperture Radar (VideoSAR). Both of these entities are combined via the tracking algorithm to continuously track a target regardless of its velocity.

2. RADAR PRODUCTS

2.1 GMTI image

A GMTI radar system has the ability to discriminate between stationary and moving targets.[1] The first product utilized in this continuous tracking radar concept is the GMTI image where a general diagram of the image is shown in Figure 1. This image is a function of azimuth angle and range. There are two regions in this image: an exoclutter region and an endoclutter regions. A target appearing in the GMTI image will be located according to its velocity at the data collection time. If the velocity of the moving target is significant, the target will be located in the exoclutter region. In this area, the target signature does not compete with any clutter. Once the velocity of the target decreases, the target begins to transition from the exoclutter region into the endoclutter region. At this point, the target competes with the clutter during the detection process. The ability to detect the target will depend on the target's signature strength and the clutter strength. If the clutter strength is greater, the target's detection will significantly decrease. Hence, the clutter needs to be attenuated in such a way as to maximize target detection.

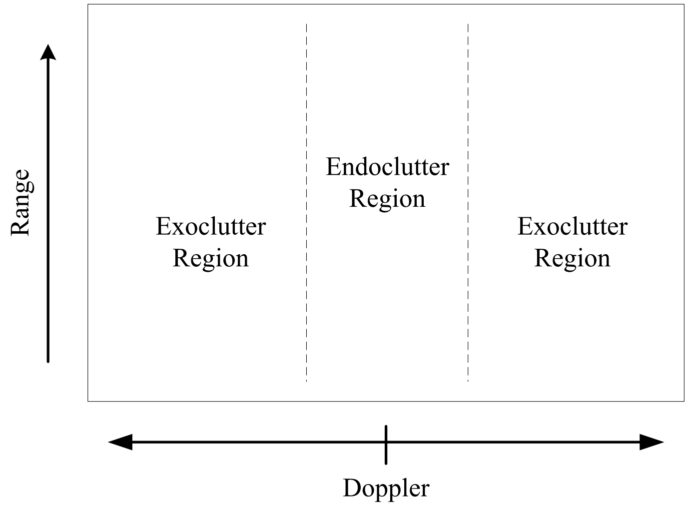


Figure 1. General diagram of GMTI image.

2.2 VideoSAR

A synthetic aperture radar (SAR) is used to image stationary objects in an area of interest.[2] This radar system produces the second product for the velocity independent continuous tracking concept. This product, known as VideoSAR, was originally introduced at Sandia National Laboratories back in the 1990s and has recently been granted a patent from the United States Patent and Trademark Office.[3]

An example of a VideoSAR snapshot is shown in Figure 2. The radar system is typically in a spotlight SAR mode at a nominal SAR pulse repetition frequency (PRF). The data is collected along circular flight paths where one flight path encompasses one aperture. In the VideoSAR product, the moving vehicles will be displaced and smeared in cross-range but their corresponding shadows will remain consistent with their true locations. An advantage of VideoSAR processing is that for very slow movers, the increased resolution reduces the backscatter from complex clutter in the endoclutter region, and increases the gain of point-like targets when compared to GMTI mode. The result is improved detection of these very slow movers.

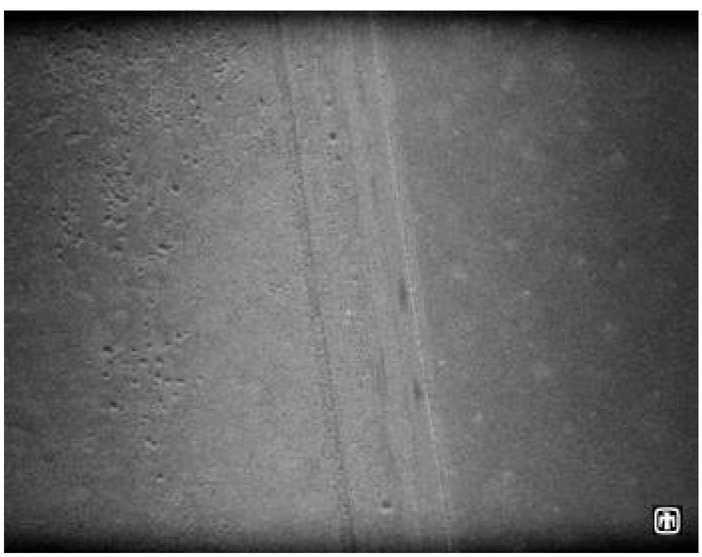


Figure 2. VideoSAR snapshot for tracking very slow moving targets.

2.3 Tracking Algorithm

In general, a SAR system produces images that assume all targets in the scene are stationary. If movers are present, the energy from the moving targets will be displaced and spread out yielding poor detection results. However, the GMTI system uses reduced coherent processing intervals to limit target spread and to detect moving targets in a scene more readily. The tracking algorithm for the approach presented in this paper combines these two systems to track a moving target throughout its entirety.

The processing for the target tracking will be accomplished in real-time. To provide a conceptual view of the algorithm, Figure 3 shows a block diagram of possible steps. The first step identifies the target of choice. Next, the target's velocity is determined. The velocity filters are applied to the target's estimated velocity where the velocity filter corresponding to the target's velocity will be utilized to continue tracking the target. Finally, a determination is made to either continue the tracking or terminate the processing.

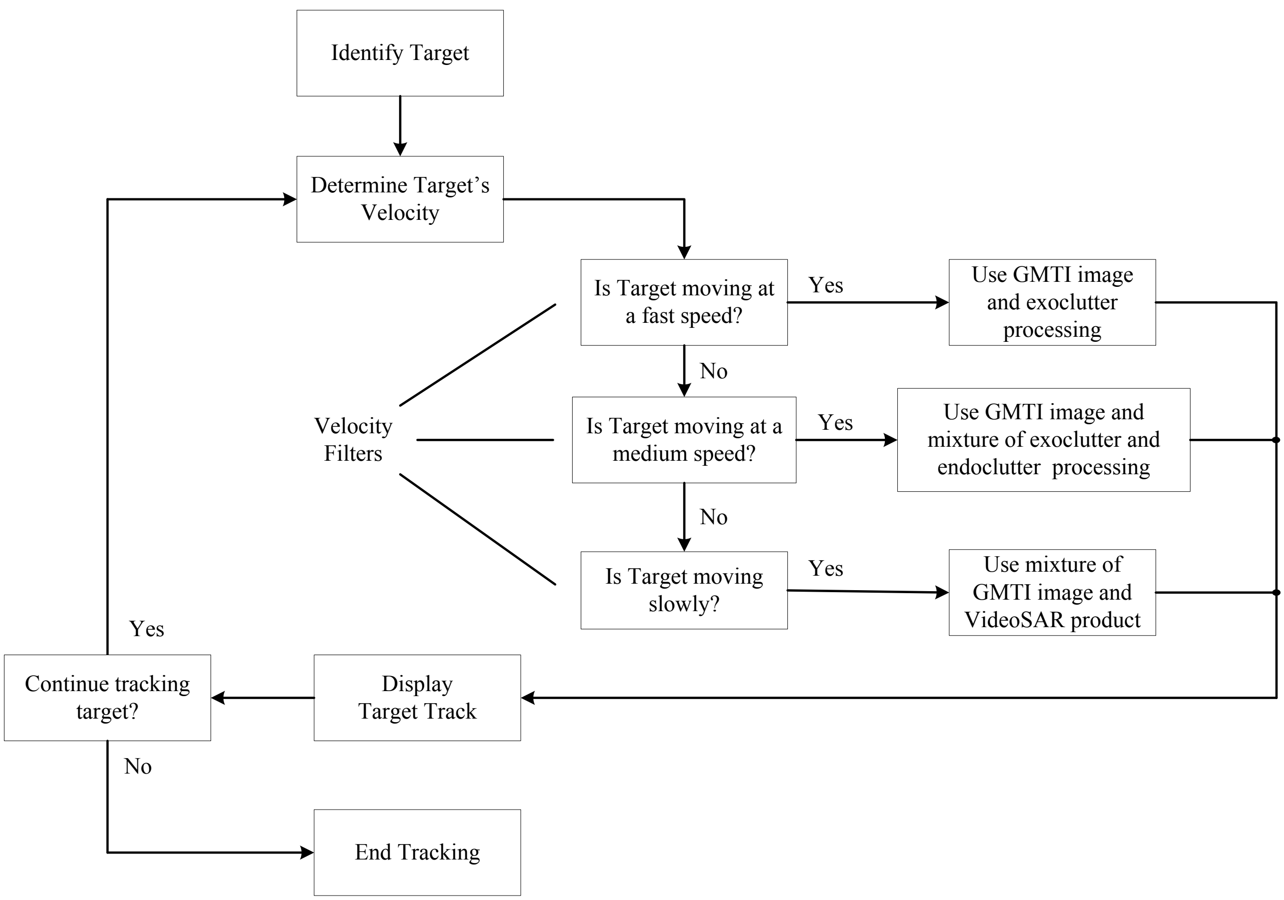


Figure 3. Conceptual processing steps for tracking algorithm.

3. SYNTHESIS OF RADAR PRODUCTS TO TRACK MOVING TARGETS

The synthesis of the GMTI and VideoSAR products for target tracking is described below. First, Figure 4 shows a GMTI image processed from data collected from one of Sandia's Ka-band radar systems. When compared to Figure 1, the endoclutter and exoclutter regions can be seen in Figure 4.

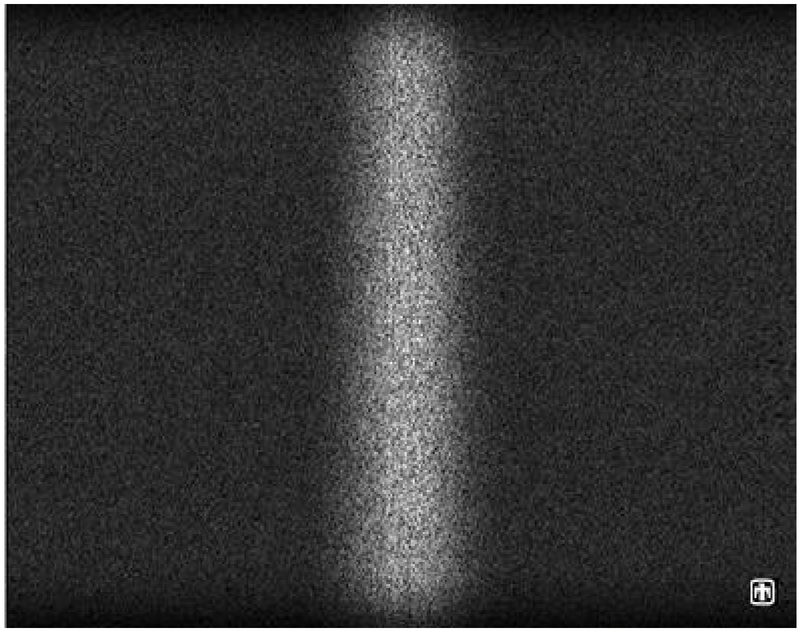


Figure 4. Generated GMTI image.

The three velocity filters used with this approach are based on whether the target's velocity can be categorized as fast, medium, or slow. Note, it is possible to tune to more than these three selected velocities if needed. If a target has a fast velocity associated with it, then the GMTI radar product would be utilized during the processing. This velocity places the target in the exoclutter region of the GMTI image as seen in Figure 5. In this particular image, two fast movers can be seen in the left side exoclutter region.

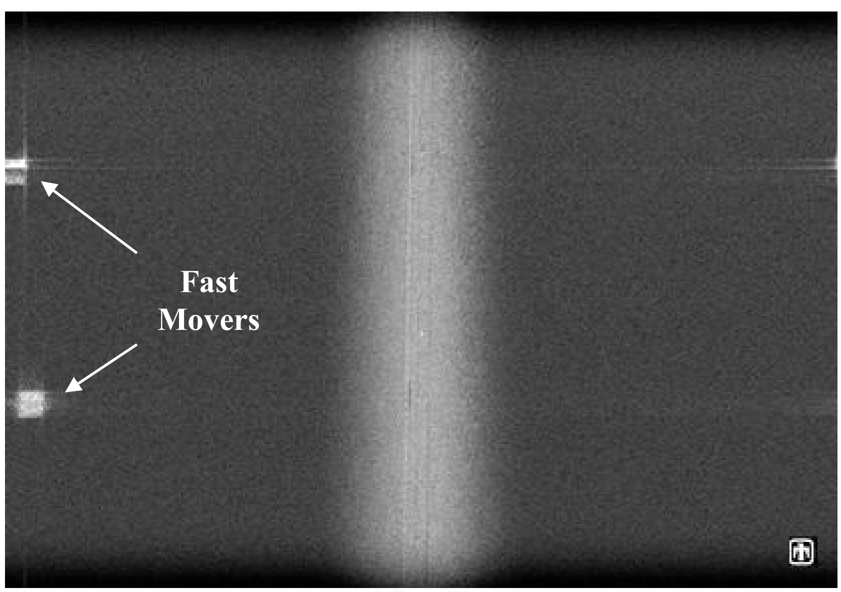
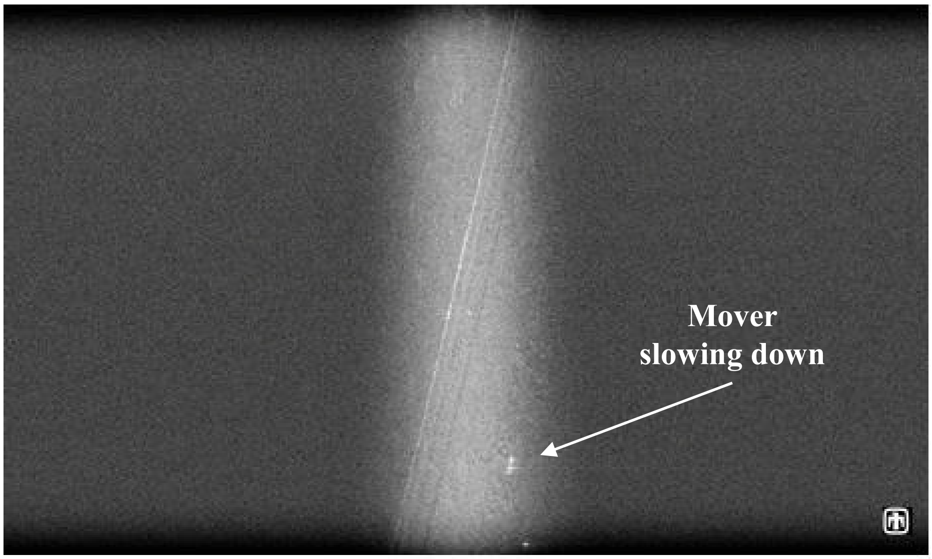


Figure 5. Fast movers in the exoclutter region.

As the velocity of the mover decreases such that its velocity can be categorized as a medium-rate velocity, the mover begins to transition towards the endoclutter region as shown in Figure 6a. As the target moves into the endoclutter region, the target becomes harder to detect because it begins to compete with the clutter. In order to increase the probability of detection, clutter cancellation techniques can be implemented to yield results similar to those shown in Figure 6b.

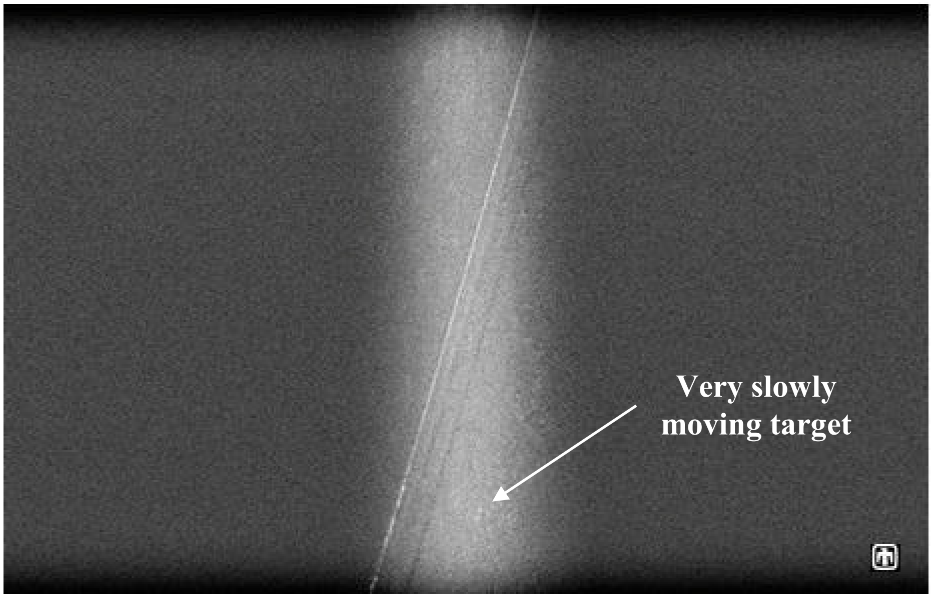


(a)

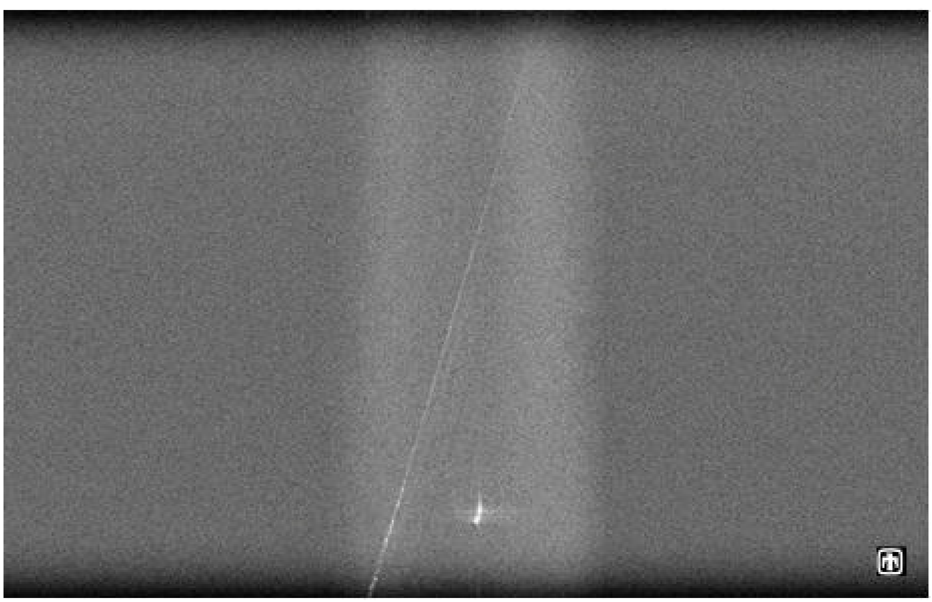
(b)

Figure 6. Fast mover decreasing its velocity and transitioning towards the endoclutter region: a) without clutter cancellation, b) with clutter cancellation

Once the target slows down considerably, it will move further into the endoclutter region. When the mover has come to a complete stop, it will disappear from the GMTI image. Data collected with one of Sandia's radar systems and a very slowly moving target is processed to yield the GMTI image in Figure 7. Figure 7a displays the resulting image without any clutter cancellation where the target is almost completely lost in the clutter. Implementing a clutter suppression technique allows the target to emerge from the clutter as shown in Figure 7b. At this point, tracking will be transferred over to the VideoSAR product. An example of the VideoSAR snapshot is shown in Figure 8.



(a)



(b)

Figure 7. Velocity of mover decreasing such that the target's response transitions farther into the endoclutter region: a) without clutter cancellation, b) with clutter cancellation.

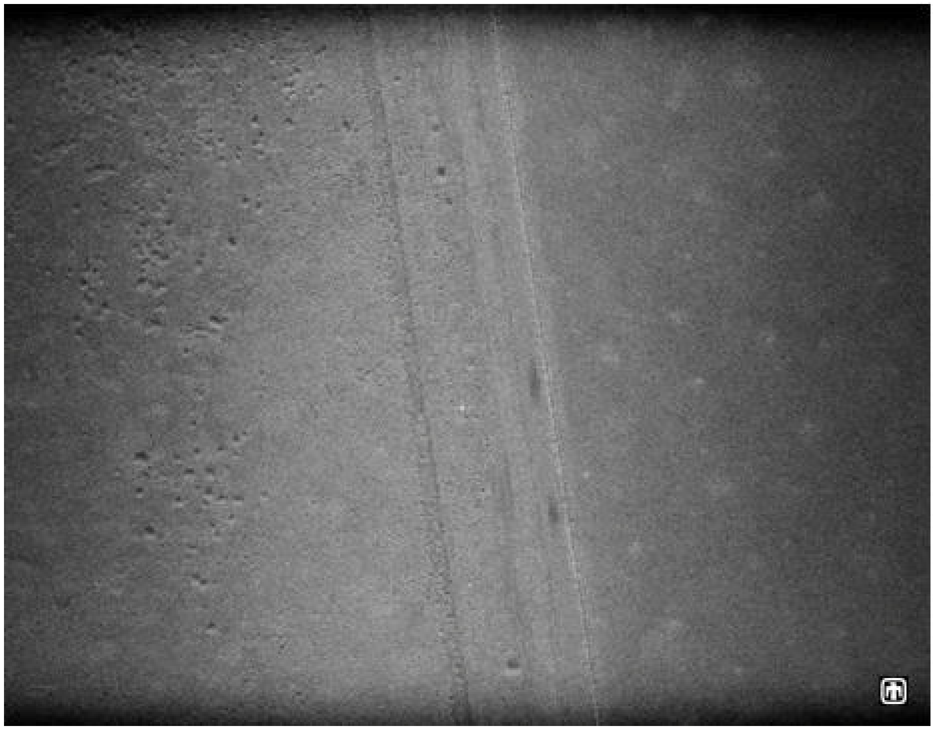


Figure 8. Collected data processed to yield an image from the VideoSAR product.

4. PRELIMINARY RESULTS

Currently, the GMTI and VideoSAR products have not been merged together to fully track a target through complete stops for a given dataset. However, the individual GMTI and VideoSAR radar products from collected data sets have already been generated separately. Moreover, target tracking has already been implemented in the GMTI exoclutter and endoclutter regions. The final merging process between the radar products will be implemented in the near future.

Figure 9 displays a VideoSAR snapshot with the corresponding GMTI image processed from a collected data set. The target dots are placed in the VideoSAR snapshot as determined from a combination of GMTI range, Doppler, and angle measurements. Note, vehicle shadows can be seen in the VideoSAR snapshot.

5. SUMMARY

A new concept for tracking a moving target completely throughout all of its velocity stages using a radar system has been presented. Two radar products were generated to act as the velocity filters for maintaining the moving target track. Future work includes final compilation of the radar products along with adjustments to the tracking algorithm to successfully track the moving target throughout its entirety.

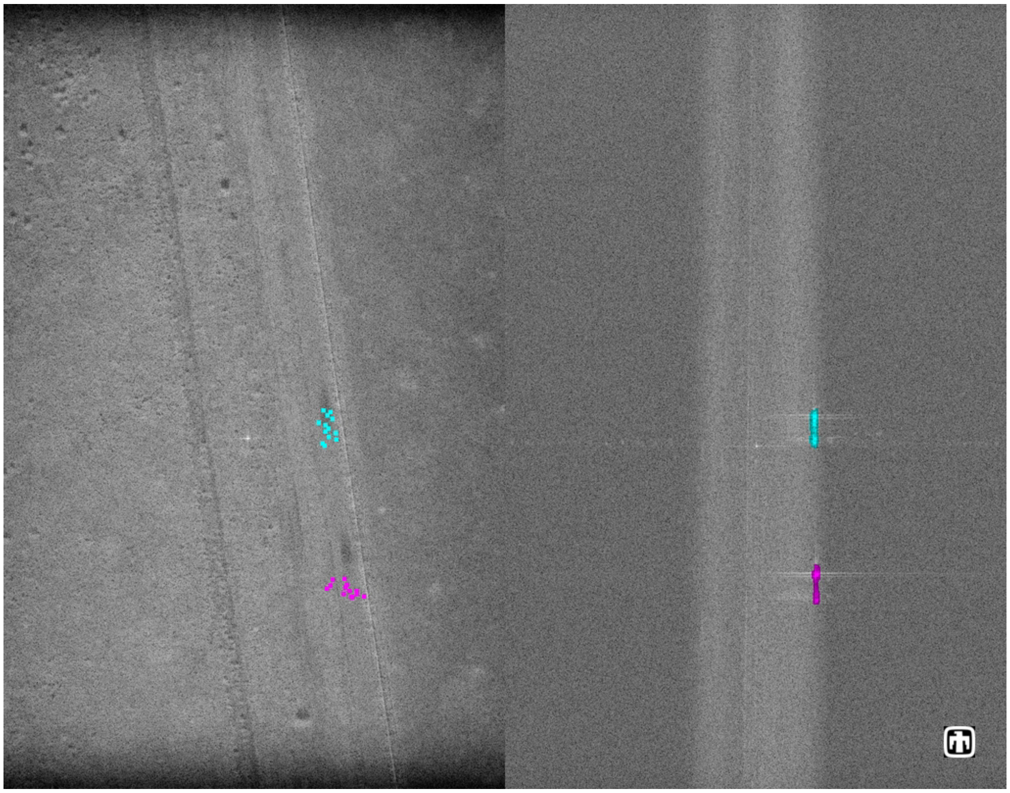


Figure 9. Processed data with two moving vehicles: VideoSAR snapshot (left) and GMTI image (right).

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