TOWARD DEVELOPMENT OF A WIDE-AREA, ALL-WEATHER, ALL-HOUR PERSISTENT SURVEILLANCE SYSTEM USING CIRCULAR SYNTHETIC APERTURE RADAR: KEY TECHNICAL CHALLENGES AND INNOVATIVE APPROACHES

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1. INTRODUCTION

In today's world, the battlefield is becoming more and more complex. This complexity grows as battles move from open field, to forest, to urban areas. Designating targets as belonging to enemy forces is becoming more and more difficult as well, given that military vehicles, civilian vehicles, bicycles, humans, animals etc., are now commonly used to conduct military operations. Thus, identification of complex targets in complex battle areas is very important and extremely challenging. Persistent staring radar utilizing circular synthetic aperture radar (CSAR) represents one promising technology to address the aforementioned issues. This research introduces technical challenges and innovative solutions to address these challenges.

SAR data collection using a circular flight path is known as circular SAR (CSAR) [1]. In CSAR, the radar moves around a circular flight path while steering its main-beam to constantly illuminate a specific ground patch. Antenna steering is accomplished either mechanically or electronically. CSAR data collection can be viewed as spotlight SAR data collection. However, the difference is that in CSAR the data is collected using a circular path while in spotlight SAR data is collected using a straight flight path. CSAR data collection geometry is presented in Figure 1.1

This circular path span is from 0 to 360° which is known as azimuth coverage or aspect angle, ϕ. The line of sight (LOS) distance from the radar to the imaging scene center is the *slant range*. The angle between the slant range to the ground plane is called the elevation or depression angle, θ.

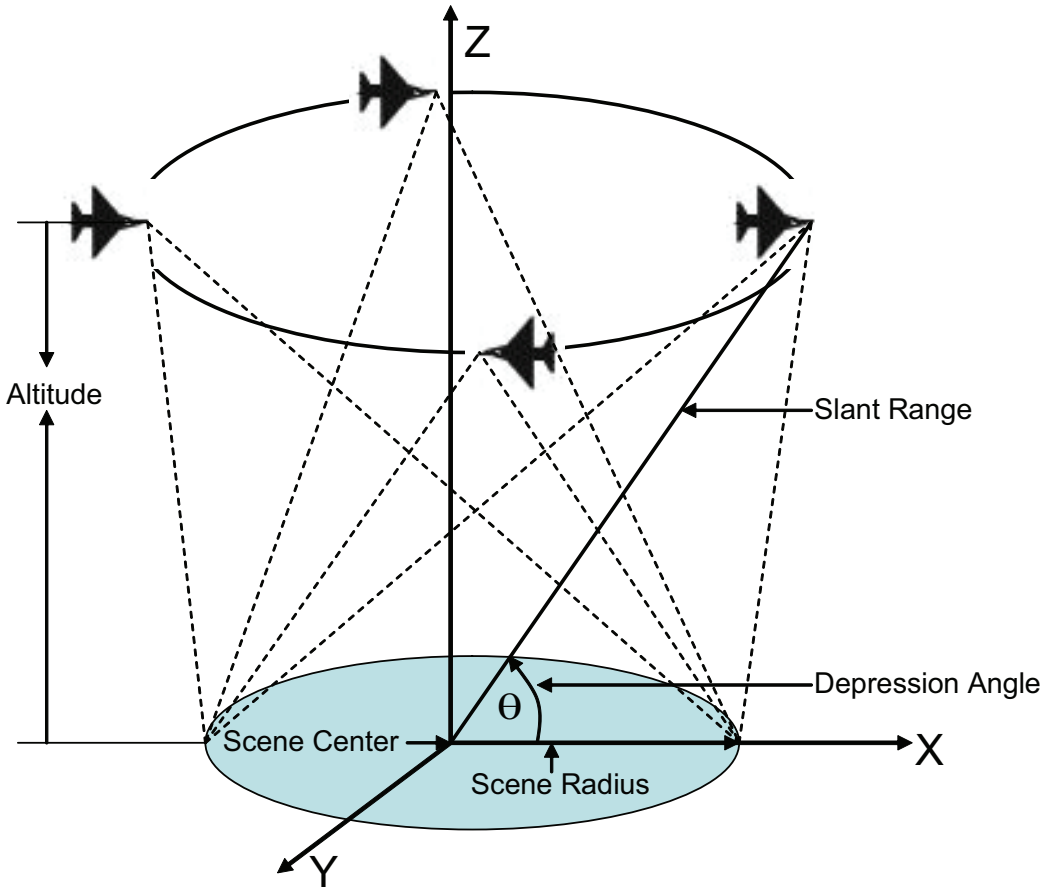

Fig. 1.1. Circular SAR (CSAR) data collection geometry. The aircraft carrying the radar flies around a scene of interest. The radar radiation pattern remains constant on the scene.

2. CSAR ENABLED EXPLOITATION PRODUCTS

Exploitation products enabled by CSAR technology are: Video SAR, CCD and NCD, GMTI.

2.1 Video Synthetic Aperture Radar:

Video Synthetic Aperture Radar is a movie generated from SAR phase history data. General scheme to produce a video SAR is integrating about 3 degree aperture (say, 0 - 3 degree) equivalent of pulses and form a SAR image. Next, produce another SAR image by overlapping the subaperture (say, 1.5 - 4.5 degree). This process is continued until entire azimuth coverage of 360 degree. Usually, each image frame (with 3 degree aperture) is updated in 1 Hz.

2.2 Coherent and Non-coherent Change Detection:

In Non-Coherent Change Detection (NCD), two SAR images are formed from two consecutive passes representing the same ground area. Assumed that both images are aligned perfectly (finer geo-registration achieved), then amplitudes of the images are correlated (subtracted) and a changed image is formed. This is called NCD. In Coherent Changed Detection (CCD) both amplitude and phase are correlated (subtracted) and a changed image is formed. CCD is more robust than NCD. However, CCD algorithm implementation is much harder.

2.3 Ground Moving Target Detection and Tracking:

Ground Moving Target Indication (GMTI), Geolocation, and Tracking with zero minimum detectable velocity (MDV) is one of the most important applications of

SAR. However, GMTI algorithms developed thus far is not matured and hence this is a very active research area.

2.4 Dismounts Detection and Tracking

Dismounts detection, geolocation, and tracking is also a new research area. Not much research has been published that addresses detecting dismounts from HALE radar.

2.5 Forensics Processing

Forensics processing to track and understand insurgent activity is also an active research area and not much work has been done.

2.6 Ultra-High Resolution SAR Image

Centimeter resolution SAR image formation using Ultra wide apertures or Three-dimensional image formation using a single pass is also a current research topic of interest

3. TECHNICAL CHALLENGES AND POSSIBLE RESEARCH AREAS

3.1 Moving Target Detection, Geolocation, and Tracking in real-time:

This is a very complex problem in particular tracking 5-10 vehicle simultaneously.

3.2 Dismounts Detection, Geolocation, and Tracking in real-time:

This is also a very complex problem; in particular higher radar frequency (X-band or Ku-band)selection versus higher Bandwidth (1 GHz at X-band vs. 0.5 GHz in Ku-band

3.3 Radar Phase History Data Compression:

CCD based phase history data compression will be necessary to reduce raw radar data size

3.4 Data Transmission Communication:

Radio Frequency data transmission (10-20 Gbps) will be required

3.5 Innovative Sensing to reduce the data rate

Compressive sensing or other novel approach

3.6 Real-time Processing

4. SUMMARY

This report presents applications of circular synthetic aperture radar (CSAR) for all-weather, all-hour wide-area surveillance. CSAR exploitation products include video SAR, coherent and non-coherent change detection (CCD and NCD), ground moving target indication (GMTI), geo-location and tracking, forensics processing, and 2D/3D super resolution SAR image formation for DoD and other applications. Significant research needs to conducted in the area of GMTI for multiple targets detection and tracking. This includes advanced radar system design (MIMO) and development of advanced radar signal processing algorithms.

LIST OF REFERENCES

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[1] M. Soumekh, *Synthetic Aperture Radar Signal Processing.* New York, NY: John Wiley & Sons, Inc., second ed., 1999.

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