High Resolution Millimeter Wave SAR for Moving Target Indication

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Synthetic aperture radar (SAR) is an imaging radar technique that provides mapping of static ground scenes. Some existing and forthcoming SAR systems thereby provide very high resolution in the centimeter domain. While high azimuth resolution is achieved by signal processing techniques, range resolution for a traditional frequency modulated system is solely dependent on the signal bandwidth. For millimeter wave (mmW) SAR, operating at frequencies roughly between 30 and 100 GHz, a signal bandwidth of several hundred megahertz or even in the range of gigahertz is achievable. While mmW SAR is generally well suited for ground moving target indication (GMTI), especially at very slow radial target speeds, higher speeds may cause effects that not only displace moving targets but smear and defocus them considerably if not letting them disappear at all. This makes it difficult for GMTI algorithms to detect such targets. Additionally, smearing and defocus are more severe and disturbing at higher resolutions. We analyze the conditions where mmW SAR GMTI works fine, show simulated and real examples of moving targets at 35 GHz with FGAN MEMPHIS and compare them to L-band SAR data.

SAR systems working in the mmW domain have some clear advantages as well as disadvantages over other, more conventional systems when GMTI algorithms are applied. The small antenna aperture reduces smearing and defocusing effects of moving targets while at the same time, the small wavelength is very sensitive to minor movements. Unfortunately, the same small wavelength also leads to high Doppler frequency shifts requiring either a very large system PRF or additional target information to solve velocity measurement ambiguities.

We showed for simulated as well as real data how much targets are smeared and defocused at small and large target velocities in high resolution mmW SAR, and we compared simulated results to low resolution images and also to those of an L-band SAR. Overall, mmW high resolution SAR seems well suited for low speed GMTI and less so for fast moving targets. Still, because of the small antenna aperture, it is a SAR solution for GMTI that offers good detection probabilities.

**THEORY**

- Range Smear
  - due to Radial Velocity

- Azimuth Defocus
  - due to Radial Target Acceleration
  - and Tangential Target Velocity

- Displacement in Azimuth
  - due to Radial Target Velocity

- Azimuth Frequency Spectrum
- Typical SAR System Parameters

**SIMULATIONS**

MEMPHIS 800 MHz

MEMPHIS 200 MHz

E-SAR 100 MHz

**EXPERIMENTAL DATA**

MEMPHIS Image Resolution: 19 cm

2 Pkw all-purpose vehicles, moving on a runway in range at 15 m/s.

Truck on a highway moving with 10 m/s in range and 28.5 m/s in cross-range.

True Vehicle Dimensions: 4.6 m x 1.7 m

Smeared and Defocused: 17 m x 7 m

Displacement: ~5 - 15 m

Truck photographed by the ground reference measurements team.

Highway as seen by a camcorder from the SAR carrier.

**CONCLUSIONS**