

A GROUND-BASED ARC-SCANNING SYNTHETIC APERTURE RADAR (ArcSAR): SYSTEM AND APPLICATION

Hoonyol Lee¹, Seong-Jun Cho² and Kwang-Eun Kim²

¹Department of Geophysics, Kangwon National University (hoonyol@kangwon.ac.kr)

²Korea Institute of Geosciences and Mineral Resources (mac@kigam.re.kr, kimke@kigam.re.kr)

1. INTRODUCTION

Ground-Based SAR (GB-SAR) systems have been actively developed recently not just as an alternative to satellite SAR systems but with its own merit of accuracy and repeatability for regional applications [1]-[12]. We are currently developing a new ground-based Arc-scanning Synthetic Aperture Radar (ArcSAR) system mounted on a truck for better resolution and operational convenience. The ArcSAR system acquires images by transmitting and receiving microwave signals through the antennae attached to the end of the extendable boom. The boom is mounted on top of the platform that rotates by the circular rail guide. The RF part of the system is mainly composed of a vector network analyzer, microwave amplifier, microwave switch system, and a notebook computer. Any kind of antenna can be attached to the boom as long as its weight and shape do not harm the stability of the system.

A stepped-frequency microwave signal is generated from the vector network analyzer. The signal is sent to the selected polarization of the Tx antenna by the microwave switch system. The signal returned from the target is collected by the Rx antenna with a particular polarization selected by the switch system. The data are then stored to the hard disk of the notebook computer for the SAR focusing. The system has the different geometry from the conventional linear-scanning GB-SAR system and requires new focusing algorithms to produce images out of the scanned data.

The ArcSAR system can operate in two different scanning modes: the spot mode and the scan mode (Fig. 1). In the spot mode, the antennae attached to the end of the boom can rotate in azimuth direction, enabling continuous look to the designated target area. The coherent integration arc is as long as the half-circle of the scanning boom to produce higher resolution than the conventional linear-scanning GB-SAR systems [1][2]. In the scan mode, the antennae are fixed relative to the boom during the scan. The data can be obtained continuously during the rotation so that it can image the whole azimuth angle (360°) around the system. The coherent integration arc is shorter than the spot mode producing lower resolution, but still has advantage in resolution when compared to the real aperture radar.

In this paper, we present the development of ArcSAR system and the new focusing algorithms for two different scanning modes. Based on the geometry similar to the Polar Format Algorithm and considering the processing costs, the Deramp-FFT algorithm is used for the spot mode while the Range-Doppler algorithm is used for the scan mode.

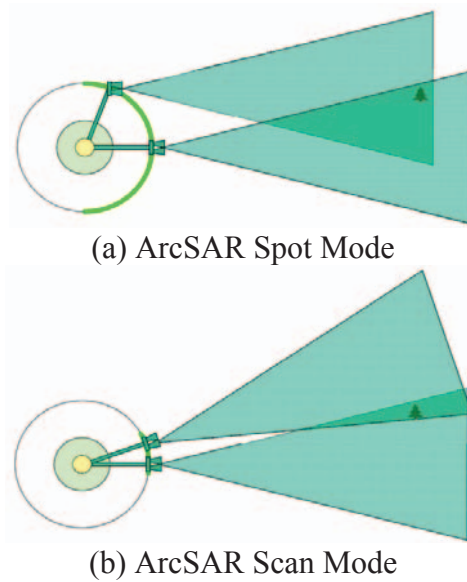


Fig. 1. Two scanning modes of ArcSAR. The spot mode (a) produces high resolution image over the area overcasted by the antenna footprint due to the longer coherent-integration-arc (green arc), while the scan mode (b) can image 360° area around the system with low resolution but still higher than the conventional real-aperture radar system.

2. RESOLUTINONS

The resolutions and their ratios from the various ground-based radar systems are listed in Table 1. Azimuth angular resolutions (in radian) and their ratios are depicted as formulae in the lower half triangle of the table, while ratios of X-band system are in the upper half triangle as an example. The X-band system has the wavelength of 0.031 m, the azimuth antenna width of 0.15 m, the length of the boom 4 m, the coherent integration arc of for the ArcSAR Spot Mode, and the linear scanning GBSAR length of 4 m (the same as the boom) for comparison. As expected, Arc-scanning Real Aperture Radar (ArcRAR) will have the poorest resolution because the azimuth resolution is simply the beam width of the antenna. The resolution of the ArcSAR Scan Mode will be enhanced by 11 times over the ArcRAR. ArcSAR Scan Mode is 4.8 times and 15.2 times lower than linear GB-SAR or ArcSAR spot mode but has the advantage of omnidirectional coverage. ArcSAR Spot Mode will have the resolution 3.1 times higher than the linear-scanning GB-SAR system when compared with the equal length of the

rotational boom and linear scanning length of 4 m. By scanning in arc rather than linear, ArcSAR spot mode will have the resolution equivalent to linear scan. ArcSAR Spot Mode has 15.2 times higher resolution than ArcSAR Scan Mode, and 167.2 times over ArcRAR.

Table 1. Azimuth angular resolutions and their ratios between ArcRAR, ArcSAR Scan Mode, Linear-scanning GBSAR and ArcSAR Spot Mode. Numerical values are the ratio of resolutions based on an X-band system with $L=0.15$ m, $r=4$ m, $L_s=4$ m, $\theta_s = \pi$, and $\lambda=0.031$ m. The numbers in the parenthesis are the inverse of it.

| Azimuth Resolution | | ArcRAR | ArcSAR Scan | Linear GBSAR | ArcSAR Spot |
|--------------------|------------------------------|--------------------------|------------------------------|-------------------------|--------------------|
| ArcRAR | $\frac{\lambda}{L}$ | 1 | 9.07e-2 (11.0) | 1.87e-2 (53.4) | 5.98e-3 (167.2) |
| ArcSAR Scan | $\frac{L}{2r}$ | $\frac{L^2}{2\lambda r}$ | 1 | 2.07e-1 (4.8) | 6.58e-2 (15.2) |
| Linear GBSAR | $\frac{\lambda}{2L_s}$ | $\frac{L}{2L_s}$ | $\frac{\lambda r}{LL_s}$ | 1 | 3.18e-1 (3.1) |
| ArcSAR Spot | $\frac{\lambda}{2r\theta_s}$ | $\frac{L}{2r\theta_s}$ | $\frac{\lambda}{\theta_s L}$ | $\frac{L_s}{r\theta_s}$ | 1 |

3. CONCLUSIONS

The ArcSAR system was developed and mounted on a truck. Image focusing algorithms for ArcSAR were developed in polar coordinates. The Deramp-FFT algorithm was used for ArcSAR Spot Mode and the Range-Doppler algorithm for ArcSAR Scan Mode. Comparisons of image resolutions between various ground-based radar systems confirmed the advantage of ArcSAR Scan Mode and ArcSAR Spot Mode over ArcRAR and Linear-scanning GBSAR. ArcSAR Spot Mode has the equivalent linear scan length of times the radius and 167 times higher resolution than ArcRAR. ArcSAR Scan Mode has omnidirectional coverage with 11 times higher resolution than that of ArcRAR. The system was mounted on a truck and will provide a rapid response tool for various applications such as regional mapping and environmental hazard monitoring. More details on SAR processing, data acquisition and application will be added on the full paper.

4. ACKNOWLEDGEMENTS

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