Spaceborne SAR Performance Improvement By Antenna Pattern Optimization

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***Abstract* – SAR antenna pattern is the most important factor for spaceborne SAR performance. This paper describes the spaceborne SAR performance and the SAR antenna pattern optimization. In this paper, the design criteria of the antenna mask were proposed and the antenna pattern optimization techniques including the genetic algorithms (GA) and the particle swarm optimization (PSO) algorithms were applied to improve the SAR system performance. The performance results showed that the SAR system performance can be efficiently enhanced by applying the GA and PSO techniques for the KOMPSAT-5 antenna pattern.**

***Index Terms* — Spaceborne Synthetic Aperture Radar, SAR Performance, Genetic Algorithms, Particle Swarm Optimization, KOrea Multi-Purpose SATellite-5 (KOMPSAT-5).**

1. Introduction

SAR is the attractive spaceborne payload because it has all weather, day and night imaging capability. This is the reason why the SAR satellites are developed and launched in many advanced countries these days. Especially the active phased array SAR is the state-of-the-art technology which enables various operation modes including the standard mode, the wide swath mode, and the high resolution mode by electronically steering the antenna pattern without the mechanical satellite maneuver.

The major SAR payload system performance parameters are the noise equivalent sigma zero (NESZ), the ambiguity to signal ratio (ASR), and the radiometric accuracy (RA). These performance parameters are very closely related with the antenna pattern and can be improved by designing the antenna pattern efficiently.

In this paper, in order to improve the system performance, the antenna pattern synthesis algorithm by using GA and PSO as a global optimization technique was applied for KOMPSAT-5 antenna pattern generation. The performance results were compared with those of the in-orbit KOMPSAT-5 antenna pattern and showed that the performance can be improved by the newly synthesized antenna pattern.

2. Spaceborne SAR Performance

The major spaceborne SAR performance parameters are NESZ, ASR, and RA. NESZ is related with the antenna mainlobe level, ASR is related with the antenna sidelobe level, and RA is related with the antenna gain flatness [1]. Because these performance parameters are connected with the antenna pattern characteristics, the antenna mask design and the antenna pattern synthesis according to the designed mask are very important. In particular, the range ambiguity to signal ratio (RASR) for the elevation direction is as follows.

$$\mathrm{RASR} = \frac{\sum_{i=1}^{N} S_{a_i}}{\sum_{i=1}^{N} S_i} \tag{1}$$

where S_i is the desired signal power and S_{ai} is the unwanted ambiguous signal power. Figure 1 shows the SAR RASR concept and geometry [2].

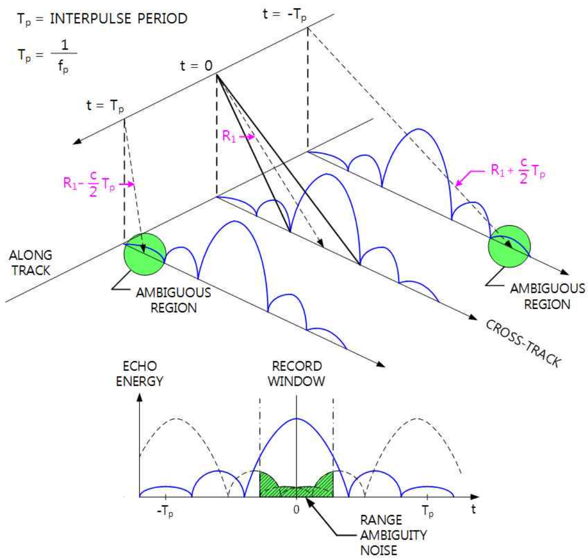

Fig. 1. SAR RASR Concept and Geometry

Range ambiguity noise results from preceding and succeeding pulse echoes arriving at the antenna simultaneously with the desired return signal [2].

In order to improve the RASR, the antenna pattern should be effectively synthesized to reduce the overlapped sidelobe into the desired mainlobe, and therefore designed to suppress the sidelobe level in the ambiguous region [3].

3. Pattern Synthesis Algorithms

The genetic algorithms and the particle swarm optimization algorithm were applied for the pattern synthesis algorithms to improve the SAR system performance.

(1) Genetic Algorithms (GA)

The genetic algorithms are evolutionary algorithms motivated by Darwin's theories of evolution and the concept of "survival of the fittest", and are techniques to optimize the object function by the recombination, mutation, and crossover processes [4].

(2) Particle Swarm Optimization (PSO)

The particle swarm optimization algorithm is high performance optimization technique and is the technique to optimize the cost function by swarm intelligence through the interaction between the particles. This technique is very simple to implement and has high convergence speed [4].

4. Optimized Patterns and Performance Analysis Results

The simulation parameters are summarized in Table I.

TABLE I
Simulation Parameters

SAR System Parameters for Simulation	
Frequency [GHz]	X-band
PRF [Hz]	4088
Satellite Altitude [km]	550
Incidence Angle [degrees]	24.20 ~ 27.19
2 Way Gain (min.) [dB]	90
Swath Width [km]	30
Element Number	32
Element Spacing	0.7 λ
RASR Requirement [dB]	≤ -20

The KOMPSAT-5 antenna pattern and the optimized antenna patterns by using the GA and the PSO algorithm are showed in Fig.2. The optimized patterns were simulated according to the summarized simulation parameters and compared with the in-orbit KOMPSAT-5 antenna pattern.

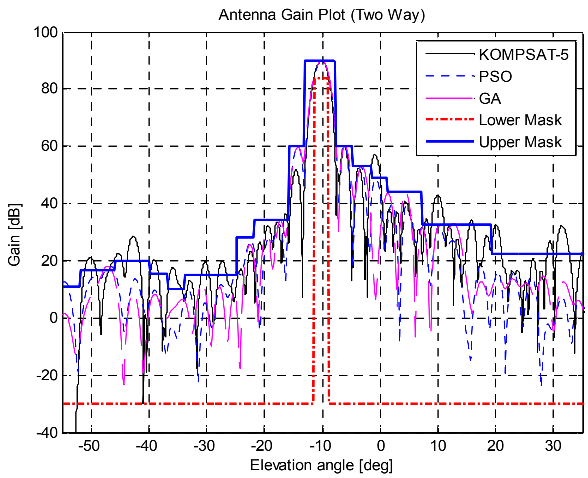

Fig. 2. The Radiation Pattern in Elevation Direction

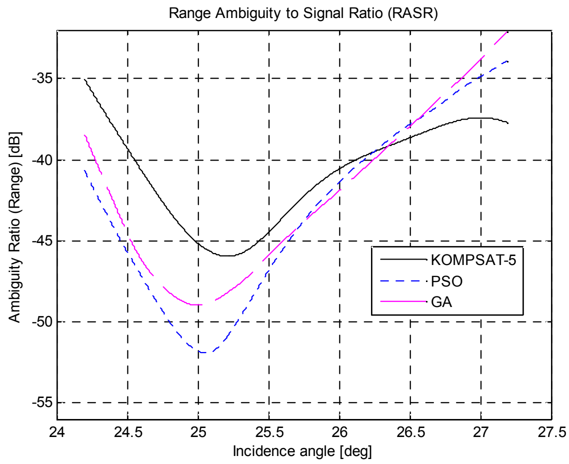

Fig. 3. The Performance Result of RASR

The performance result of RASR is showed in Fig. 3. The RASR performance can be improved about maximum 6.8 dB by PSO and 5.5 dB by GA within the swath through the effective antenna pattern optimization process.

5. Conclusion

This paper describes the SAR antenna pattern optimization to improve the SAR system performance by using the GA and PSO algorithm. The antenna pattern mask to suppress the sidelobe levels in the ambiguous region was designed and the synthesized antenna pattern to satisfy the mask was proved to improve the SAR system performance especially for RASR. The optimized antenna patterns showed that the RASR performance was improved through the comparison with KOMPSAT-5 antenna pattern.

Finally, this paper shows that the GA and the PSO techniques are very efficient and powerful for the pattern synthesis to the complex mask and applicable for spaceborne SAR antenna pattern synthesis of the active phased array SAR application.

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