Subarea Approach for Curvature Error Compensation In Spotlight SAR Imaigng Using PFA Interpolation

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***Abstract*— In SAR imaging, when the range from a platform to a target is not large enough compared to the target scene diameter, the curvature error in the mixing process can be significant and it distorts an image. In order to reduce the effect of the curvature error on the image, subarea technique is utilized when the far-field assumption is invalid. We propose the subarea technique that reduce the curvature error by reducing the size of the target area while reducing the discontinuity at the same time.**

Keywords : SAR, Phase Error, PFA, Subarea approach

I. INTRODUCTION

In SAR imaging, the platform sends chirp pulse to the target. The reflected signal from the target includes the chirp and the information of the target. We need to remove the chirp signal to restore the target image. The process is composed of mixing, low- pass filtering and range compression [1]. The process basically assumes that the radar platform operates at a standoff distance that is large compared to the target scene diameter. Under this assumption, it can be well approximated by a planar wave-front. Otherwise, the curvature error generated in mixing process can cause significant error when the data interpolates from the polar format to Cartesian format in spotlight SAR signal processing using a PFA(Polar Format Algorithm) as shown in Figure 1. This limits the scene size when we use the PFA. One of the approaches to reduce the effect of mixing error is subarea technique proposed by W. G. Carrara [2]. However, subarea approach have been showed some drawbacks in the scene dividing and composing process. Image cutting sometimes introduces a noise that influences on SAR imaging. And the discontinuity can occurs at the boundary while combining the sub-areas. We analyze the subarea technique procedure and its effect on the image and propose the algorithm to lessen the side-effect in the division and composition process.

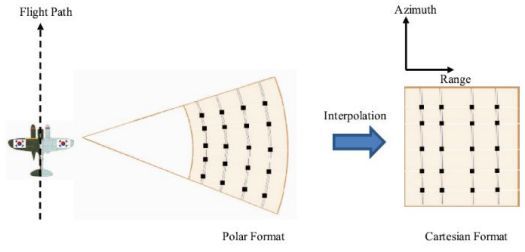


Fig. 1. PFA curvature phase error

II. PROPOSED ALGORITHM DEVELOPMENT

The subarea technique conducts the image formation process individually for an individual subarea. Each subarea has its own scene center and conducts own motion compensation and algorithm as shown in Figure 2. The polar interpolation of the received data is performed separately for each subarea. The size of an each subarea is determined small enough to restrict scene size-dependent effects to an acceptable level. And we combine subareas together to produce a full sized scene. The procedure is described in Table 1. The division of the azimuth and range can be directly implemented from the varying reference signal considering step 2 in Table 1. The division along the azimuth and range can be achieved by dividing the flight path and reflected time from the target respectively as shown in Figure 3(a). Using the reflected time, we can distinguish from which subarea the target reflected. The aircraft transmits the microwave to the target using radar in order to obtain the information of the target area. The aircraft collects the reflected signal by using the already known information such as scene size, center position and the range.

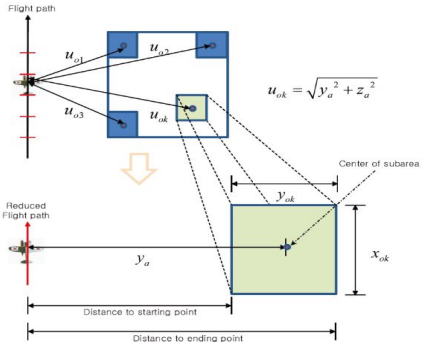


Fig. 2. Subrange technique combined with sub-aperture technique

TABLE I. Procedure of subarea technique

Step1	Divide the original scene into subareas to reduce the size-effects
Step2	For each subarea, select the flight path and time interval respect..
Step3	Mix the reflected signal from the each subarea using the reference signal corresponding to the center of the subarea respectively.
Step4	Process the each signal for SAR imagery using multi-process to raise the speed and the compose the image of subareas divided.
Step5	Remove the side-effect from the division and composition of images such as discontinuity at the border line.

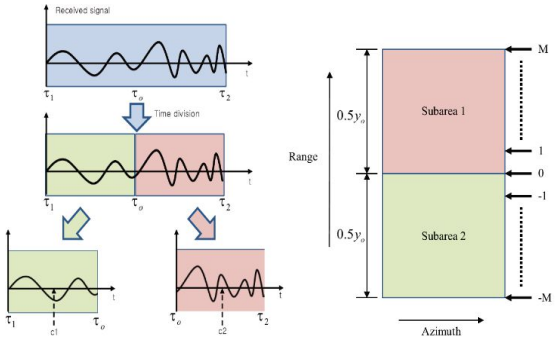


Fig.3. (a) Time division for a reference signal, (b) Scene divided into 2 subareas

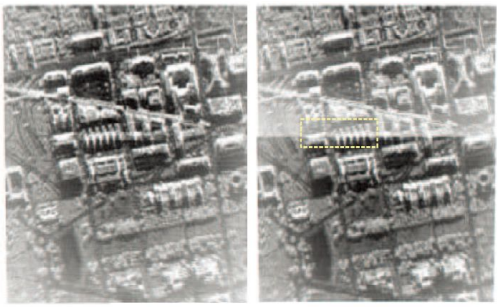
The side effect of the subarea technique is that discontinuity occurs at the boundary while combining the subareas. We propose the complement technique to remove the discontinuity caused by the subarea approach. Two processed images are made using the subarea technique when whole scene is divided into 2 subareas as shown in Figure 3(b). Let the M be the number of samples along the range direction. Actual SAR image of the target region is generally continuous. Adjacent samples are highly correlated and continuous. In this nature, averaging can be a proper solution. Firstly, we sum the values of the certain number of samples adjacent to boundary and obtain the average value after dividing by the number of samples. Then we set the values of the boundary sample with the average value. Let the number of samples averaged be w. If w is too large, then the loss of resolution can be occur although it is helpful to reduce the distortion at the boundary. Therefore, we need to select the parameter value w carefully. The corresponding simple code is given in the Table II. Let a[i] be i-th value of sample and w be arbitrary integer.

TABLE II. Averaging code at boundary in SAR image

```
for i=0:M
    a[i]=a[i]+a[i+1]+ ⋯ +a[i+w]+a[i-1]+ ⋯ +a[i-w];
    a[i]=a[i]/(2w+1);
    a[-i]=a[-i]+a[-i+1]+ ⋯ +a[-i+w] a[-i-1]+ ⋯ +a[-i-w];
    a[-i]=a[-1]/(2w+1);
end
```

III. SIMULATION RESULT

In SAR imaging process using PFA, the quality of an image gets worse by the curvature error as the target gets away from the center of the scene when the scene size is too large. However, we can overcome the problem by limiting the scene size. We simulate the subarea technique for the gray-scaled map material as shown in Figure 4. We set the distance between the targets as 70cm x 70cm, and w with 6 for averaging method. We reduce the defocusing effect and distortion in the edge using the subarea technique with 2 partitions. Comparing to the image in Figure 4(a), the blurred target area in Figure 4(b) that places far away from the center is compensated. . However, we also identify the effect of the subarea technique. The result of the subarea technique shows the discontinuity at the junction area as shown in Figure 4(b). We simulate our proposed algorithm. More detailed description for the boundary of Figure 4(b) is given in Figure 5(a). We achieved some compensation of discontinuity using averaging with w=6 as shown in Figure 5(b) compared to the Figure 5(a). We analyze that the discontinuity is caused by the blurring effect of the curvature error. The discontinuity does not disappear even in subarea with 2 partitions because the curvature error is not still eliminated clearly seeing the result as shown in Figure 4. This problem can be solved by increasing the number of subarea but this can also result in the loss of resolution. Because there is a trade-off between the continuity in the edge and the resolution.



(a) (b)

Fig.4. Discontiuity at the boundary in SAR image (a) original, (b) 2 partitions

(a) (b)

Fig.5. Image Comparison at the boundary (a) Subarea combined image (b) Subarea combined image with averaging (w=6)

IV. CONCLUSION

We have considered the curvature error that occurs during the mixing process in PFA. We utilized the subarea technique in order to reduce the effect of the mixing error. However, the subarea approach has some disadvantages because of the scene dividing and composing process. Thus, we analyze the subarea technique procedure and its effect on the image to propose the algorithm to compensate side-effects in the process of division and composition. We developed the averaging technique using adjacent samples in order to remove such a discontinuity and demonstrate the performance by the SAR imaging simulation using the subarea technique.

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