Frame Rate Computing in Video SAR Using Geometrical Analysis

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Abstract - *In this paper, we propose a new approach in order to determine frame rate (FR) of video synthetic aperture radar (Video SAR or ViSAR). FR is a systemic characteristic in designing ViSAR systems which is affected by several issues in a radar system. In the previous works, relevance of FR and some issues such as signal processing for image formation, central frequency and pulse repetition interval (PRI) has been specified. Now, we wish to introduce a new overview on determining FR in terms of video frame quality and imaging geometry. Towards this purpose, we analyze ViSAR geometry and find a relevance between FR and radar platform's height based on geometrical computations.*

Keywords: Synthetic Aperture Radar (SAR), Video SAR (ViSAR), Frame Rate (FR), Imaging Geometry.

1 Introduction

ViSAR is used for providing video of a region of interest (ROI) in remote sensing. Such videos allows us to have a better observation and monitoring on an area for tracking moving objects. ViSAR is indeed a new mode of SAR imaging technology and has been introduced recently. In fact, ViSAR can provide facilities of a video along with specific features of SAR imaging system, i.e., weather-independent and all time imaging. An optical video system may not be applicable in the night or bad weather; however, if we use a ViSAR system, it can provide video for different applications such as surveillance in all time and all weather. A main topic in design of ViSAR systems is to determine a suitable FR in accordance with video quality index and radar systemic design factors for human visual system (HVS). According to a related work [1], a good order of center (or central) frequency of a ViSAR is about 200-300 GHz. According to [2], moving to this high frequency can generate a high frame rate video. This paper is organized as follow. In the second section, we review some details of FR in the previous researches. In the third section, we suggest a new additional condition on computation of FR based on ViSAR geometry and video quality. Final section is conclusion.

2 Background and Related Work

In ViSAR, for having FR > 5 Hz, we need to a center frequency around 200 GHz [2]. Due to this high center frequency (needed for ViSAR mode of a SAR system), the synthetic time (T_{syn}) required to obtain a proper cross-range or azimuth resolution will be highly low (in SAR systems, rage resolution, which is a description of another dimension of image, is based on general computations of radar and it is usually adjusted to be equal to azimuth resolution because like an optical image, resolution of two orthogonal dimensions must be similar). Thus, signal processing for image formation in ViSAR mode has relatively more complexity. Some related works [3]-[5] have proposed new ways towards this challenge by improving imaging block. Now, we are going to review on ViSAR geometry and frequency design based on T_{syn} of radar system.

A sample geometry for ViSAR is illustrated as Fig. 1 [1]. According to [1], the platform flies along a circular flight path around a fixed scene centered at a constant elevation H, with the antenna directed inward and perpendicular to the platform heading, enabling a persistent surveillance of the ROI. R_g and φ denote the radius and depression angle of the circular path, respectively. Ground output coordinate system (GOCS) is defined by two mutually perpendicular axes x and y on the ground, and θ is the aspect angle. According to SAR imaging theory, cross-range resolution is dependent on the center wavelength λ and the synthetic angle $\Delta\theta$ as below.

$$\delta_a \approx \frac{\lambda}{2\Delta\theta} \tag{1}$$

By replacing $\Delta\theta = VT_{syn}/R_g$ and $\lambda = c/f_c$ into the above equation, the relationship between the synthetic time T_{syn} and the center frequency f_c is given by

$$T_{syn} \approx \frac{c R_g}{2\delta_a V f_c} \tag{2}$$

where V is the velocity of the platform and c is the speed of light. By ignoring the imaging processing time, FR can be approximated as

$$FR \simeq \frac{1}{T_{syn}} \approx \frac{2\delta_a V}{cR_g} f_c \quad (3)$$

From this last equation, the FR will be proportional to the center frequency. As a consequence, to achieve a high FR, the center frequency of ViSAR have to be set to minimize the imaging delay made by the synthetic time. With the high center frequency of ViSAR, a small synthetic aperture is sufficient to achieve the required cross-range resolution, thus the entire circular trajectory consists of multiple synthetic apertures. For each aperture, it has the same small angular extent $\Delta\theta$ and different center angle θ_k, where k denotes the index of aperture [1].

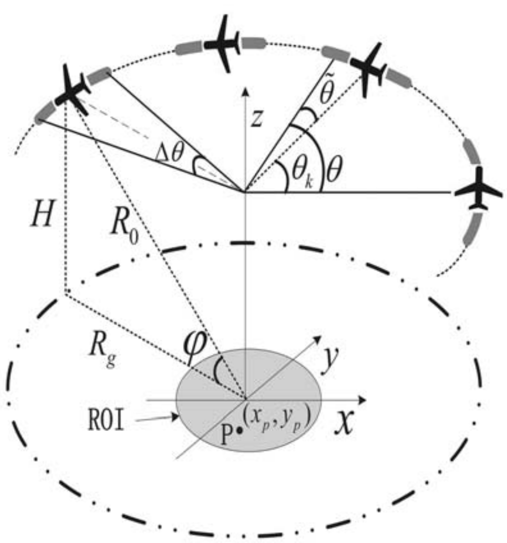

Fig. 1 ViSAR geometry [1].

In addition, a similar analysis on FR has been done in [6]. In that work, the authors have tried to consider dynamic changes of the target scene in terms of platform velocity along with other usual factors of azimuth resolution and center frequency for FR computing.

3 Frame Rate Computing Based on Imaging Geometry (Radar's Height)

Based on our work, FR needs to consider another condition that must be noted. It is indeed to have attention to scene dynamics (including radar platform velocity and target mobility) and video quality requirements. If $\delta_o = \delta_r = \delta_{az}$ is the initial spatial resolution of video frames in terms of both directions such that with varying the height of radar platform, it is not modified based on SAR equations (due to needs to different transmission power and view angle in spotlight mode). In this condition, δ_H is corresponding resolution of each H and proportional to the height (H); $\delta_H \propto H$. Δt is the time interval for moving from initial place to a second place by moving target, so FR must satisfy the following condition.

$$FR \geq \frac{1}{\delta_H \Delta t} \quad (4)$$

where Δt is computed by $\Delta t = \Delta r / V_o$ where V_o is maximum of relative velocity between the target and radar platform and Δr is the total movement of target on the ground in which $H\Delta r \propto \Delta y^{-1}$ (it is now assumed that the movement and sensor are collinear). Δy is also computable by the following equation.

$$\Delta y \cong \sqrt{r_2^2 + H^2} - \sqrt{r_1^2 + H^2} \quad (5)$$
$$r_2 = \Delta r + r_1$$

where r_i (i=1,2) are the initial and final place (location) of a moving target during imaging by ViSAR sensor. As a final combination of all above cases, we can approximately represent FR_{min} as below.

$$FR_{\min} \propto V_o \Delta y = V_o \left(\sqrt{r_2^2 + H^2} - \sqrt{r_1^2 + H^2}\right) \quad (6)$$

Now, FR must be according to the above equation and this equation must be considered as new requirement in systemic design of ViSAR in addition to all the previous conditions described in the past researches. For example, H can affect f_c. Some marginal/asymptotic evaluations are given as below:

$$H = 0 \rightarrow FR_{min} \approx \frac{V_o}{\delta_o} \left| r_1 - r_2 \right|$$
$$H = +\infty \xrightarrow{\Delta y \approx 0} FR_{min} \approx 0$$

4 Conclusion

We stated the problem of FR computing in ViSAR. In here, we represented a simple formula for this computing, however for future work, some other parameters of an imaging system based on ViSAR geometry can be added to complete this finding.

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