EFFICIENT CONFIGURATIONS OF SAR SENSORS FOR IMPROVED RANGE RESOLUTION

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1. INTRODUCTION

In recent years, the study of constellation of SAR (Synthetic Aperture Radar) sensors has become of great interest. This is due to the possibility to build low-mass and low-cost SAR sensors each one with limited resources, but able to work together thus retrieving a performance level comparable, or even better, than usual SAR systems. When using such a constellation of SAR sensors, the main advantages are represented by the robustness to failures as well as the capability of system reconfiguration. The main drawbacks are the limited performance capability of the single sensor, and also the synchronization issues. The single sensor limited performance capability is the price to be paid for reducing mass and costs. To make cheaper and lighter the single sensor, one might reduce the system bandwidth, at the expense of a reduced range resolution. In [1] a technique for improving range resolution by exploiting multiple surveys of the same area has been described. This technique allows a maximum theoretical improvement factor in range resolution equal to the number of surveys, if proper off-nadir angles are selected, see also [2]. On the other hand, in [3] an analysis on efficient collection geometries for a spotlight MIMO (Multiple Input Multiple Output) SAR has been presented. The idea proposed in [3] exploits mutually orthogonal waveforms used by different sensors, each one equipped with a transmitter and a receiver. In particular, different sensors are displaced in the along-track direction forming non-contiguous monostatic sub-apertures. By exploiting bistatic returns it is possible to form virtual sub-apertures able to fill the non-contiguous monostatic sub-apertures, thus leading to a long contiguous synthetic aperture, which ensures high resolution in the along-track direction. The strength of this approach resides in the possibility to increase the along-track resolution of a factor greater than the number of SAR sensors. The same idea has been exploited differently in [4] and [5] for a multi-platform ISAR environment.

2. EFFICIENT CONFIGURATIONS FOR RANGE RESOLUTION IMPROVEMENT

The idea proposed in [3] can be extended to the cross-track direction and combined with the technique in [1], thus leading to efficient configurations of SAR sensors for increased resolution in the range dimension. In fact, the range resolution cell obtained after chirp compression can be treated as the illuminated region corresponding to an equivalent aperture of length L_1' having a beam width $\Delta\theta_1^{eq}$, as sketched in Figure 1.

The expression of the equivalent beam width $\Delta\theta_1^{eq}$ as a function of the off-nadir angle θ_1 and of the bandwidth of the transmitted chirp B can be obtained considering that the projection of the equivalent beam in the ground range direction has to be equal to the achievable ground range resolution:

$$\text{ground range resolution cell} = \frac{\lambda}{\Delta\theta_1^{eq} \cdot cos(\theta_1)} = \frac{c}{2B \cdot sen(\theta_1)} \Rightarrow \Delta\theta_1^{eq} = \frac{2\lambda \cdot B \cdot tan(\theta_1)}{c}, \tag{1}$$

being λ the carrier wavelength, and c the speed of light.

The range resolution can be increased by incrementing the corresponding equivalent aperture (i.e. incrementing $\Delta\theta^{eq}$). This can be done by considering several SAR sensors observing the same area on the ground with different off-nadir angles, as proposed in [1]. In particular, a constraint on the selection of the off-nadir angles has to be posed in order to avoid gaps in adjacent apertures. To determine such a constraint, we consider a second sensor observing the same area on the ground with an off-nadir angle $\theta_2 = \theta_1 - \Delta\theta$, transmitting a chirp with the same bandwidth B. Recalling (1), for this second sensor we get:

$$\Delta\theta_2^{eq} = \frac{2\lambda \cdot B \cdot tan(\theta_2)}{c} = \frac{2\lambda \cdot B \cdot tan(\theta_1 - \Delta\theta)}{c}. \quad (2)$$

The two observations (i.e. the two equivalent apertures) result contiguous if the following relation holds:

$$\Delta\theta = \frac{\Delta\theta_1^{eq}}{2} + \frac{\Delta\theta_2^{eq}}{2} = \frac{\lambda B}{c} tan(\theta_1) + \frac{\lambda B}{c} tan(\theta_1 - \Delta\theta). \quad (3)$$

Being $\Delta\theta$ small, (3) can be solved by a first order Taylor series expansion, leading to:

$$\Delta\theta \cong \frac{\lambda B}{c} tan(\theta_1) + \frac{\lambda B}{c} tan(\theta_1) - \frac{\lambda B}{c}\frac{\Delta\theta}{cos^2(\theta_1)} \Rightarrow \Delta\theta = \frac{2\frac{\lambda B}{c} tan(\theta_1)}{1 + \frac{\lambda B}{c \cdot cos^2(\theta_1)}} \quad (4)$$

If the sensors are able to transmit mutually orthogonal waveforms, the approach in [3] can be applied with a resulting range resolution improvement factor greater than the number of sensors. The resulting geometry is sketched in Figure 2 for the simple case of two SAR sensors. In particular, the equivalent apertures L_1' and L_2' are obtained by Sensor 1 and Sensor 2 respectively, working as usual monostatic systems. Equivalent aperture L_3' is obtained when Sensor 1 transmits and Sensor 2 receives, thus leading to a bistatic acquisition. Geometry has to be selected according to (4) in order to avoid gaps between adjacent apertures. A detailed analysis of the possible geometries will be presented in the final paper. Returns from the three different apertures have to be processed coherently to achieve the maximum allowed resolution improvement factor. In the final paper, the effectiveness of the proposed technique in terms of achievable increase in range resolution will be demonstrated on simulated SAR data.

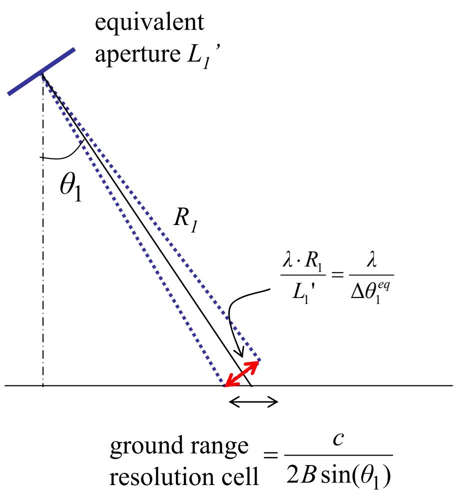

Figure 1 – Range resolution and equivalent aperture

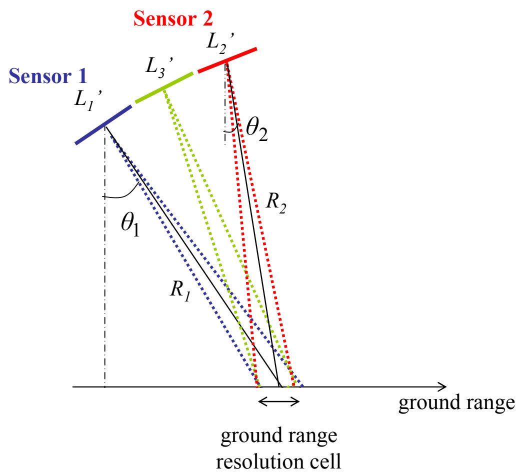

Figure 2 – Equivalent apertures using 2 sensors

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