ICEYE MICROSATELLITE SAR CONSTELLATION STATUS UPDATE: LONG DWELL SPOTLIGHT AND WIDE SWATH IMAGING MODES

Vladimir Ignatenko[1], Matthew Nottingham[1], Andrea Radius[1], Leszek Lamentowski[1], Darren Muff[1]

[1]ICEYE Oy, Maarintie 6, 02150 Espoo, Finland

ABSTRACT

The ICEYE constellation features the first operational microsatellite based X-band SAR sensors suitable for all-weather day-and-night Earth Observation. ICEYE microsatellites feature an active phased array antenna with beam steering capabilities in the along and cross-track directions, that allow ScanSAR and TOPSAR modes to be operated. Additionally, lightweight platforms are more agile and have better mechanical pointing capabilities that enable very long dwell, staring Spotlight modes. In this paper we report on both of these aspects and on the status of the ICEYE constellation and describe the characteristics of the aforementioned modes.

***Index Terms*—** SAR, X-band, ICEYE, TOPSAR, Spotlight, SAR-video

1. INTRODUCTION

The ICEYE constellation is a system intended for persistent near real time monitoring anywhere on Earth. Presently the commercial constellation consists of several second-generation ICEYE X-band SAR satellites, providing nearly daily access to any location on the globe. The launch mass of a single satellite is under 100 kg., allowing a large number of spacecraft to operate with a reasonable cost. Further plans see the ICEYE constellation growing with enough satellites to enable persistent access within a few hours and enable daily repeat passes for interferometry as well as coherent change detection.

The main characteristic of spacecraft and its X-band SAR payload, together with an assessment of the first commercial modes were presented in [1]. The second generation ICEYE SAR microsatellites carry a 300MHz bandwidth instrument, and target the full spectrum of commercial SAR applications from 15-meter resolution wide scans to sub-meter resolution Spotlight imagery.

This paper demonstrates the capability of the ICEYE microsatellites to operate the wide swath TOPSAR mode, that enables for the first time satellites with less than 100 kg to cover large areas. In Section 3 typical examples of ultra-high staring Spotlight mode are presented, showing the impact of increased dwell time. The paper is concluded in Section 4.

Table 1. System parameters of the ICEYE GEN 2 sensors

SYSTEM PARAMETER	SPECIFICATION VALUE
carrier frequency	9.65 GHz
look side	both LEFT and RIGHT
antenna size	3.2 m x 0.4 m
PRF	2-10 kHz
range bw	40-300 MHz
peak power	4 kW
polarization	VV
incidence angle (stripmap)	10-30
incidence angle (Spotlight)	20-35
mass	85 kg

2. ICEYE SAR SENSOR TOPSAR IMAGING MODE

TOPSAR mode [2] is an extension of the ScanSAR mode, with advantages of near uniform SNR (reduced scalloping effect) and Distributed Target Ambiguity Ratio (DTAR). TOPSAR mode employs azimuth beam steering, and every burst of this mode can be processed similar to sliding Spotlight acquisition.

Table 2. Typical TOPSAR configuration for ICEYE constellation

PARAMETER	VALUE
Number of beams	4
azimuth resolution (meters)	< 15
azimuth steering angle range (deg)	-0.75:0.75
Target Doppler bandwidth (Hz)	500
burst time (s)	0.37
imaged area (rg x az km)	100 x 100

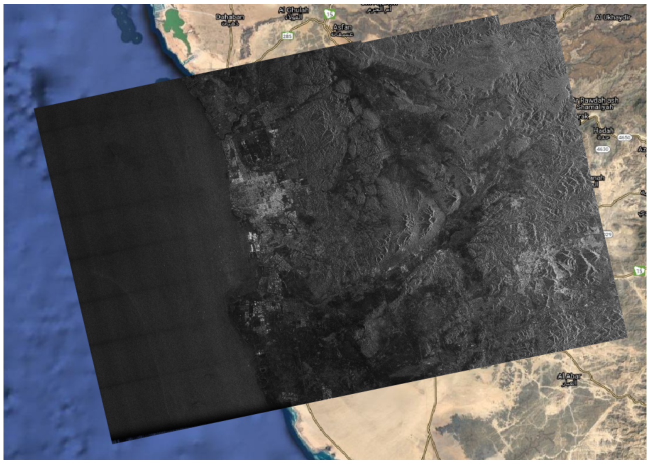
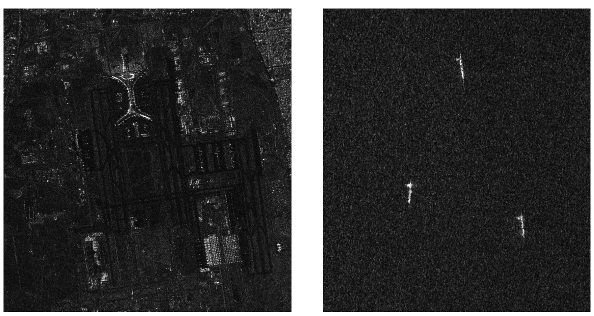


Fig. 1. An image acquired in TOPSAR mode from ICEYE SAR satellite constellation over the Jeddah and Mecca in Saudi Arabia on January 17th, 2020 (size approximately 127 km x 85 km - range x azimuth). Overlaid on top of Google Earth base-map.



3. LONG DWELL STARING SPOTLIGHT MODE

In staring Spotlight mode [3] the mechanical antenna steering in the azimuth direction is used to increase the illumination time, resulting in an increased synthetic aperture and therefore, increased azimuth resolution. Figure 2 shows an example of a multi-looked with 12 looks and ground range detected image with resolution of 0.5m azimuth and 0.5 meters in slant range.

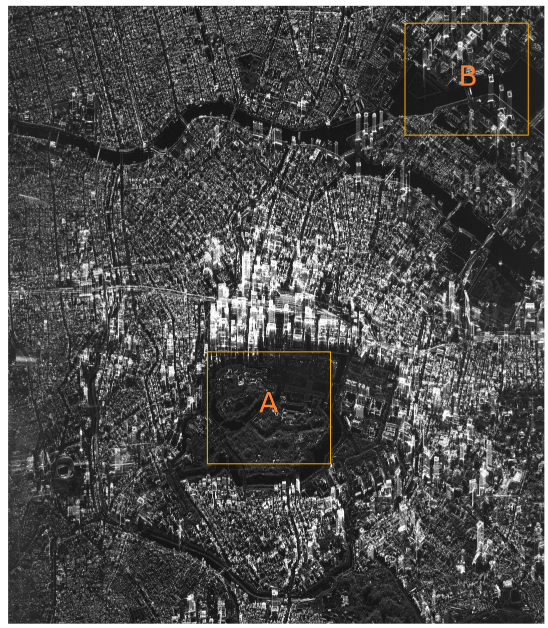


Fig. 2. An image acquired with long dwell staring Spotlight mode from the ICEYE SAR constellation over the downtown region of Tokyo Japan on January 17th, 2020 (size approximately 6 km x 6 km, dwell time 25 seconds, number of looks 12)

With the increased dwell time of staring Spotlight acquisitions, more looks of the ultra-high resolution images can be produced, and incoherently summed up, leading to an increase in SCR and the suppression of speckle noise (Fig. 3, 4).

Fig. 3. Patch A Fig. 2 with dwell time of 2 sec. (1 look)

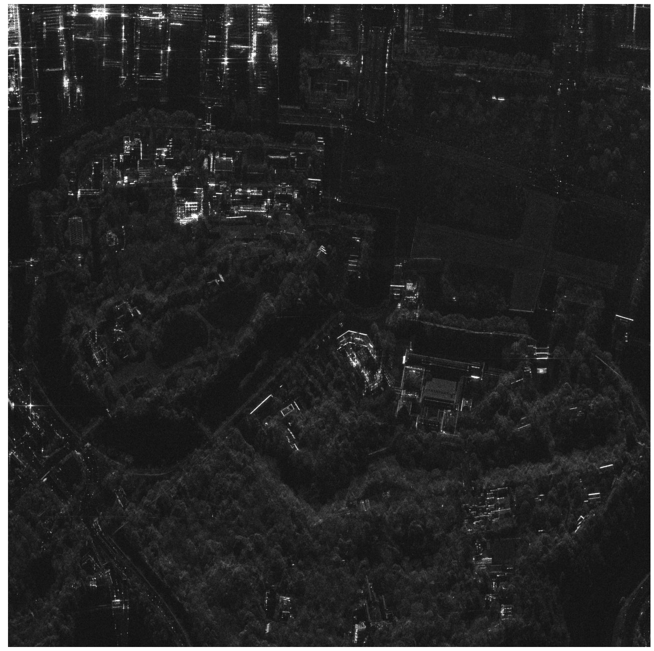


Fig. 4. Patch A Fig. 2 with dwell time of 14 sec. (7 looks)

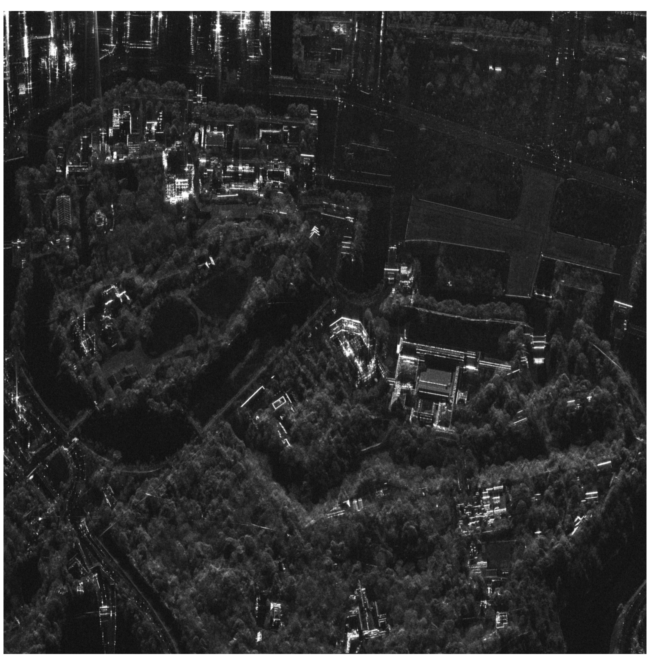


Fig. 5. Patch A Fig. 2 with dwell time of 25 sec. (12 looks)

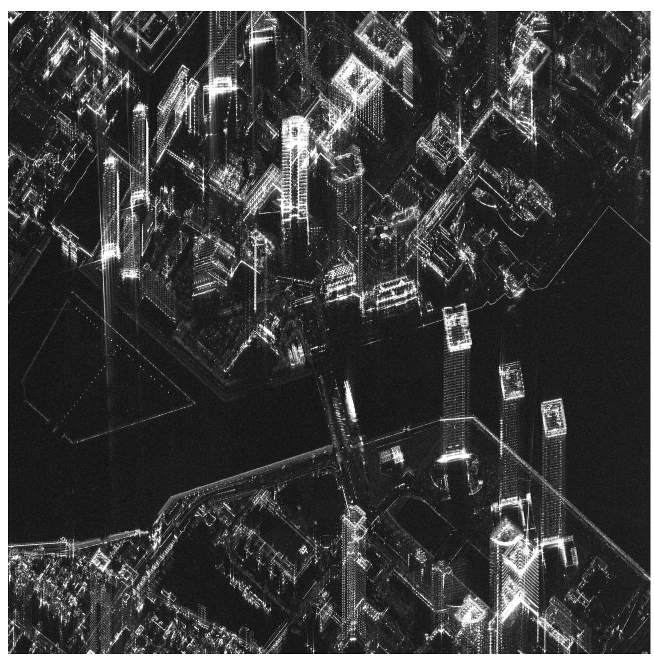


Fig. 6. Patch B Fig. 2 with dwell time of 25 sec. (12 looks)

3.1. SAR-video

Very long dwell time staring Spotlight imaging enables not only ultra high resolution imaging, but as well utilisation of looks as video frames, allowing for observation of dynamical phenomena.

Fig. 7. Color composite of long dwell acquisition looks (video frames)

4. CONCLUSION

In this paper, we have presented an extension of the imaging capabilities of the ICEYE SAR constellation, and demonstrated wide swath and ultra high resolution modes from a microsatellite of under 100 kg class. The constellation capabilities will be extended to the new satellites that will ensure that an operational availability with a higher revisit time will be achieved, allowing the near real time monitoring of phenomena with fast dynamics and enabling a large amount of applications such as SAR interferometry and Coherent Change Detection.

5. REFERENCES

[1] V. Ignatenko, P. Laurila, A. Radius, L. Lamentowski, O. Antropov, and D. Muff, "Iceye microsatellite sar constellation status update:evaluation of first commercial imaging modes," in *2020 IEEE International Geoscience and Remote Sensing Symposium*, 2020.

[2] F. De Zan and A. Monti Guarnieri, "Topsar: Terrain observation by progressive scans," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 44, no. 9, pp. 2352–2360, 2006.

[3] J. Mittermayer, S. Wollstadt, P. Prats-Iraola, and R. Scheiber, "The terrasar-x staring spotlight mode concept," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 52, no. 6, pp. 3695–3706, 2014.