Doppler Frequency Performance of KOMPSAT-5 Measured from Worldwide Uniform Backscattering Coefficient Area

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ABSTRACT: The estimation accuracy of Doppler centroid frequency is important to process azimuth focusing and to provide well-focused SAR images. Basically Doppler frequency can be evaluated from roll/yaw/pitch or quaternion measured from attitude sensor, but additional Doppler shift due to mechanical mismatch between payload and bus and electrical mispointing from synthetic error of phased array antenna. Therefore, it is important to check estimation accuracy of Doppler centroid frequency by measuring it from uniform backscattering coefficient area.
In the paper, the estimation accuracy of KOMPSAT-5 Doppler centroid frequency will be presented. To show it, image data acquired from three uniform area and one corner reflector was used. Finally, it will be presented that KOMPSAT-5 payload and bus attitude pointing is very good by exhibiting difference between two Doppler frequency measured from uniform area image and evaluated from attitude data was small.

1. Introduction

KOMPSAT-5 is Synthetic Aperture Radar (SAR) satellite whose center frequency is X-band and it has been launched at 22/Aug/2013. It was designed to operate with three basic mode called as HR (High Resolution, Spotlight Mode), ST (Standard, Stripmap Mode) and WS (Wide Swath, ScanSAR mode) before launch. After Aug 2016, four additional modes which upgrade resolutions of three basic modes was updated which is called as Enhanced Standard (ES), Enhanced High Resolution (EH), Ultra High Resolution (UH) and Enhanced Wide Swath (EW), which enhance resolution compared to the basic operational mode.
Total 7 operational mode of KOMPSAT-5 was summarized in Figure 1. Number for each mode is proportional to incidence angle. Blue and green box means the beam that the resolution and swath-width requirements was assigned.

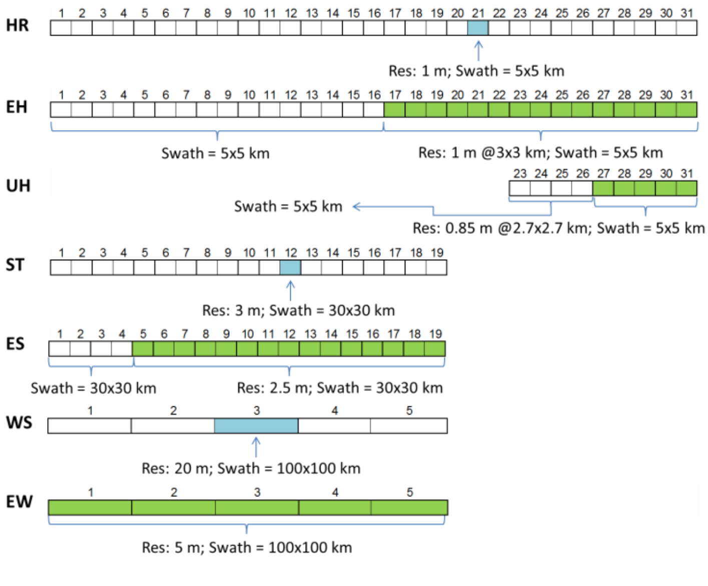

Figure 1. KOMPSAT-5 basic and enhanced operation mode

Doppler centroid frequency is one of the important parameters to measure satellite performance. SAR satellites are usually designed to point zero Doppler direction in order to make accurate and precise SAR image processing result. Yaw or yaw/pitch steering technique are applied to maintain SAR satellite beam pointing on zero Doppler plain. However, actual beam pointing cannot be exactly on zero Doppler plain because of many unwanted effects, such as inaccurate control system, inaccurate sensor, amplitude/phase error of each TR module, and so on.
In principle, it is possible to calculate the Doppler centroid from orbit and attitude data, but measurement uncertainties these parameters (primarily attitude) will limit the accuracy. Alternatively, the Doppler centroid can be estimated from the received complex echo data [1].
In the paper, it will be presented that KOMPSAT-5 payload and bus attitude pointing is very good by exhibiting difference between two Doppler frequency measured from uniform area image and evaluated from attitude data was small.

2. Doppler Centroid Estimation Technique and Worldwide Site

In ideal case, Doppler centroid frequency has to be zero but actually it is not zero because of many reasons. It is directly proportional to squint angle and geometric explanation about squint angle was shown in Figure 2. Squint angle becomes zero if satellite boresight was on the zero Doppler plain.

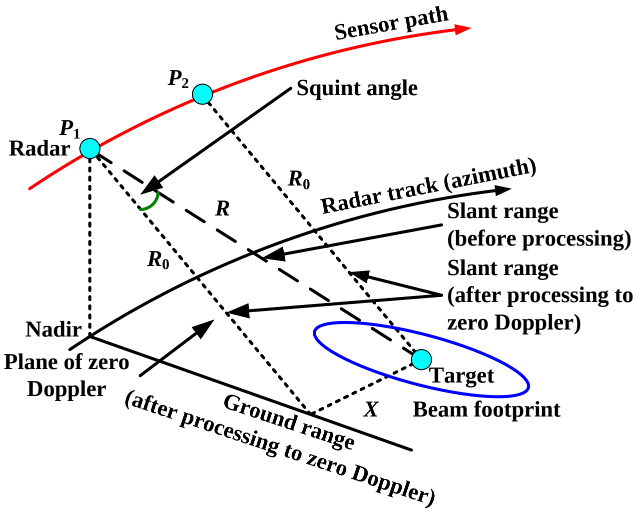

Figure 2. Geometrical relationship between squint angle and zero Doppler plain

Doppler centroid estimation can be categorized into estimation from geometry and received data, and estimation from received data also consists of magnitude and phase based estimation approach. The result of three estimation technique was based on [2].

KOMPSAT-5 images for three uniform distributed target have been acquired to estimate Doppler centroid. The LAT and LON of each distributed target was shown in Table 1. These of Canada and Cameroon site referred to CEOS SAR subgroup site (http://sarcv.ceos.org/targets/).

Table 1. LAT and LON information of distributed target

Distributed Site	Country	LON	LAT
Amazon Forest	Brazil	-65.67	-5.03
		-69.64	-5.03
		-65.67	-9.12
		-69.64	-9.12
CSA Boreal Forest Sites	Canada	-84.6078	51.26667
		-85.2481	49.65556
		-82.7606	49.29167
		-82.0228	50.89194

CSA Cameroon Rain Forest Site	Cameroon	13.48798	4.14129
		13.48798	4.13572
		12.19741	4.15119
		12.26637	2.59908

3. Doppler Centroid Estimation Results Measured from KOMPSAT-5 Data

Number of KOMPSAT-5 images acquired from uniform distributed areas and those brief beam information was shown in Table 2. January and August images were used to analyze Doppler centroid in order to check how much seasonal variation had effect on it.

Table 2. Number of images acquired from each uniform distributed area

Site	Month	ASC	DESC
Amazon	Jan	32	12
	Aug	28	42
Canada	Jan	29	22
	Aug	21	3
Cameroon	Jan	12	14
	Aug	13	11

KOMPSAT-5 BUS basically operates with geodetic pointing 33.7 degree roll angle, and yaw steering algorithm has been made based on that angle. Residual Doppler with the condition versus true anomaly angle was show in Figure 3. It means that KOMPSAT-5 Doppler centroid depends on satellite LAT position.

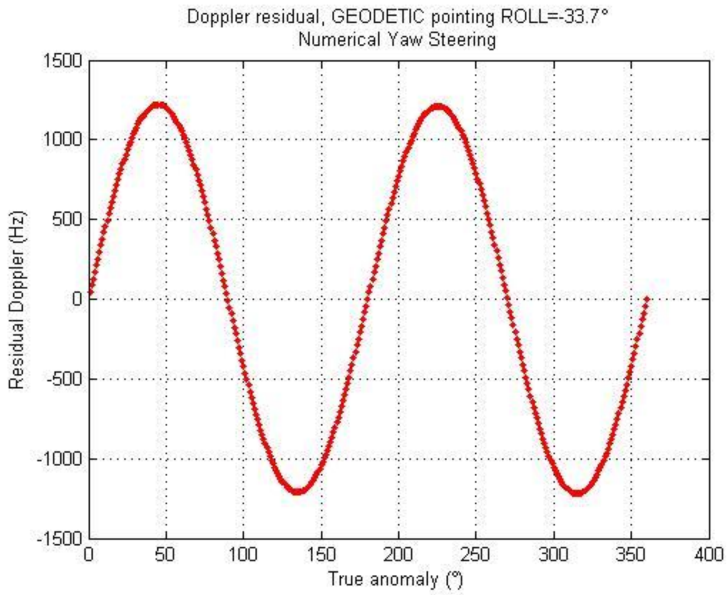

Figure 3. Residual Doppler vs. true anomaly after yaw steering

Figure 4 shows residual Doppler centroid measured from KOMPSAT-5 echo signal reflected from uniform distributed area. Blue/red/green marks mean Amazon/Canada/Cameroon site, respectively. O and X mark means DESC and ASC orbit, respectively.

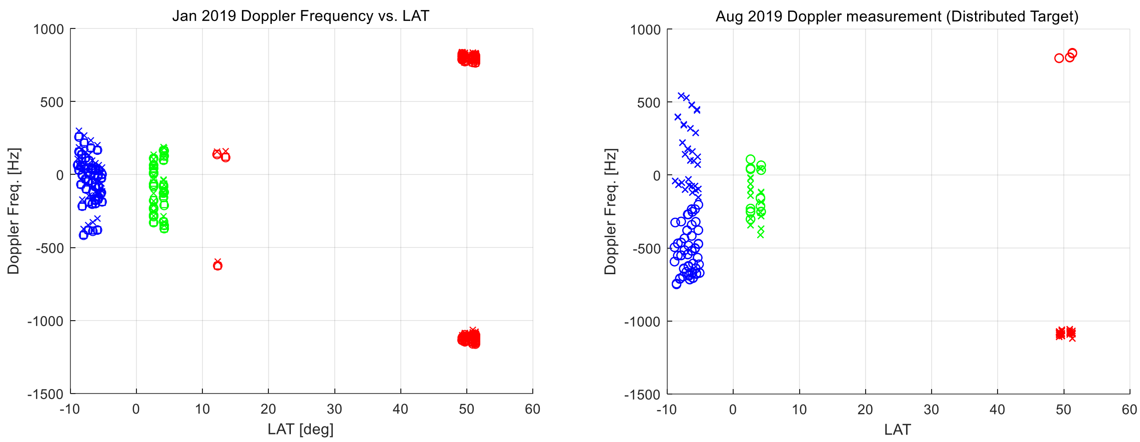

Figure 4. Residual Doppler measured from January(left) and August(right) image

In Figure 4, residual Doppler is proportional to latitude which is directly corresponding to true anomaly angle. It is noted that Doppler centroid of Canada and Cameroon site were stable. It is expected that the reason of relatively high variance of Amazon August image was caused by that not-uniform area due to Amazon forest fire were acquired during August.

Figure 5 shows Doppler centroid difference measured from ancillary and echo signal. It shares same legend with Figure 4. As expected, Doppler centroid difference between two measurement technique is small. There is little dependency on orbit type (ASC or DESC) and site. It means that KOMPSAT-5 yaw steering and phase array antenna control module are performing well until now.

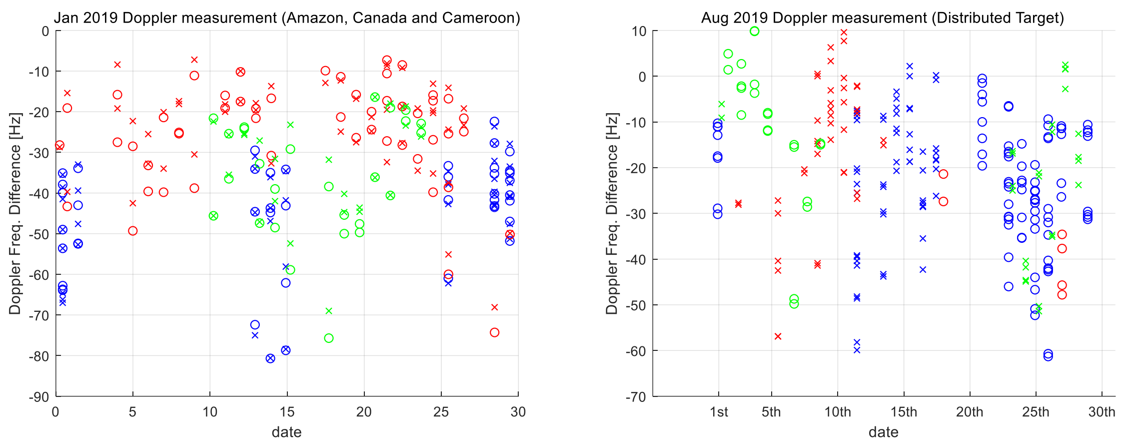

Figure 5. Doppler centroid difference measured from ancillary and echo signal

4. Conclusion

In the paper, KOMPSAT-5 Doppler centroid estimation results were presented. Many images acquired from three uniform distributed area (recommended from CEOS SAR subgroup) were used to analyze Doppler centroid. January and August images were chosen to check whether seasonal variation existed or not. The analysis results show that Doppler centroid has little dependency on orbit type (ASC or DESC) and site. Therefore, it is verified that KOMPSAT-5 yaw steering and phase array antenna control module are performing well until now.

5. References

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[2] Ian G. Cumming, Frank H. Wong, 2005. Digital Processing of Synthetic Aperture Radar Data. Artech House Inc., pp. 481-566.