Automated Detection of Precipitation induced Artefacts in X-band SAR Images

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Abstract

Synthetic aperture radar (SAR) images recorded during heavy precipitation events may be severely affected as wavelengths become shorter and acquired SAR images in X - band offer the possibilities to scrutinize the disturbance on SAR images due to weather phenomena occurring in the troposphere. We investigate on the potential influence of weather effects on space-borne synthetic aperture radar imaging and in a first step we provide an estimate on the potential influence of rain (attenuation) on SAR imaging according typically weather scenarios. Hereby estimates of attenuation on microwave SAR signals through precipitation systems are provided. A theoretical evaluation of the atmospheric influence on SAR imaging is given. Moreover an algorithm will be presented which allows for an automated detection of precipitation induced artefacts in SAR images.

1 Introduction

As commercial synthetic aperture radar (SAR) satellites like TerraSAR come into operation, the control of product quality becomes increasingly of high relevance. The propagation path can under certain conditions greatly impair the imaging performance, particularly in the case of heavy precipitation events in the troposphere. Calculations of the specific attenuation [dB/km] for rain-intensities of 40 mm/hr deliver values up to 1 dB/km for radar systems operating in X–band[1, 2, 3]. Depending on the total length of the propagation path, the attenuation of the signals in X–band may add up to 20 dB considering a path length through the precipitation medium of 10 km one way traversal [4, 5].

In **Fig. 1** rain-cell affected SAR signatures recorded during the SIR–C/X mission are given. The white shading is due to direct reflections from the rain region, whereas the darkly shaded areas are due to rain attenuated (blocked) signals from the ground. This image is used in Section 2 in order to demonstrate a newly developed algorithm for detecting rain-affected areas in SAR images.

In Section 3 we conclude and furthermore an outlook of future activities related to investigations on propagation effects in SAR imaging are given.

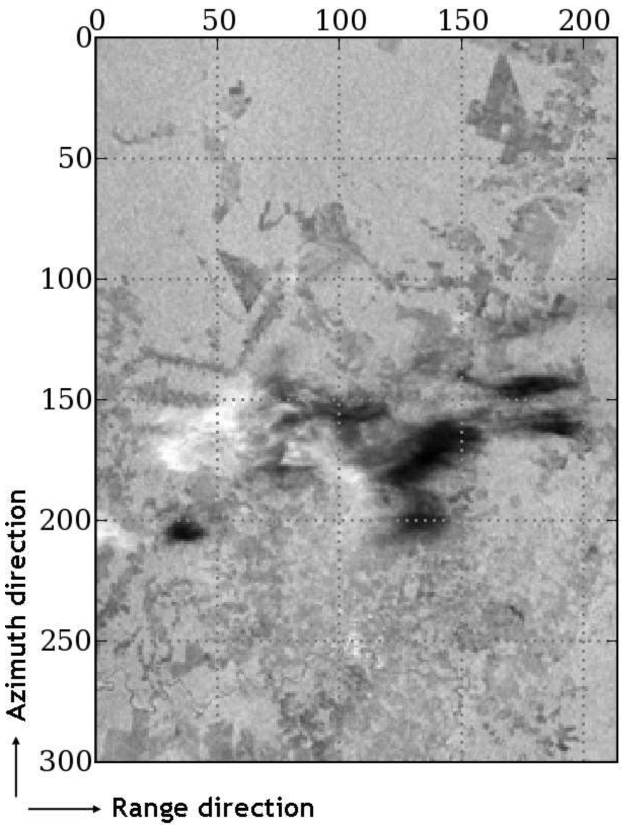


Figure 1: Demonstration using test data set - X-SAR/SIR-C Mission DLR/NASA 1994, Oct.,06 / Datatake ID: 103.60. In this example we see rain induced artefacts. The white shading is due to direct reflections from the rain re-

gion, whereas the darkly shaded areas are due to rain attenuated (blocked) signals from the ground. This image is referred as "Original image" in **Fig. 2** and is used for demonstration of the proposed detection algorithm.

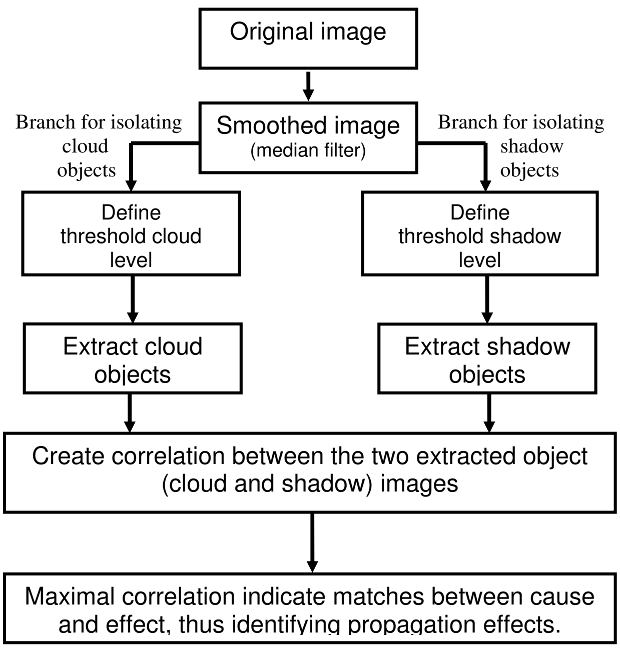


Figure 2: Flow-chart showing the main steps for a detection algorithm in order to identify recorded data sets with rain induced artefacts in SAR images.

2 Detection Algorithm

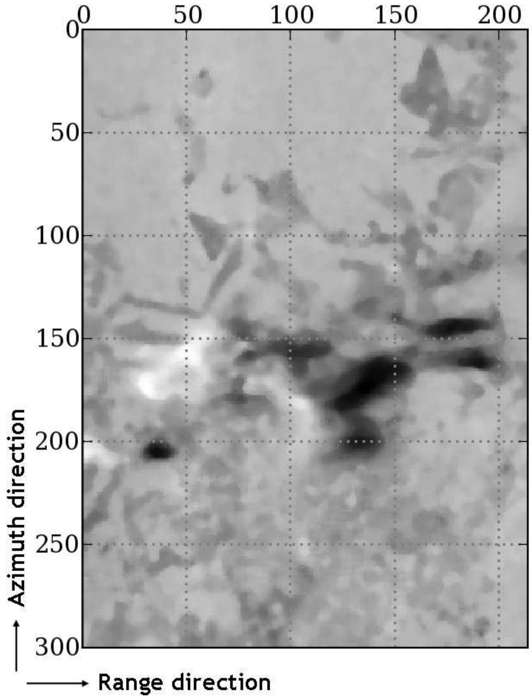
An algorithm is introduced which allows for detection of artefacts due to heavy precipitation, where an example of an affected image is given in **Fig. 1**. We embark on a strategy which is provided in the flow-chart **Fig. 2** describing the main steps in order to successfully detect artefacts due to strong precipitation. The algorithm is based on two effects that strong precipitation events may cause in a SAR images:

- Dark patches due to the attenuation of the transmitted signal through the precipitation medium
- Bright areas due to partial backscattering at the precipitation system (hydrometeors, like larger raindrops and hail)

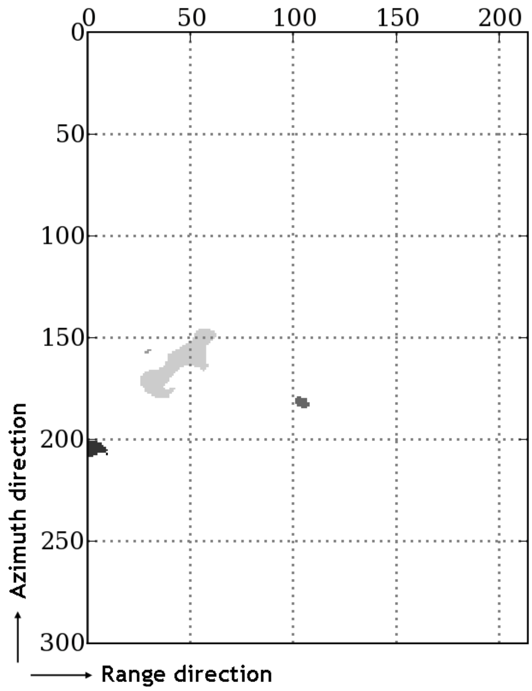
The detection of the precipitation cell signatures in SAR images is based on an a priori knowledge about the occurrence of such effects. The signal intensities obtained form attenuated regions are similar to those of a water surface or smooth areas with little signal energy scattered towards the receiver. The enhanced backscattering expected from heavy clouds could be similar to those from urban areas or manmade structures. However, the intensity variations are different. The location of the bright areas and the dark patches are interrelated in that the direction of illumination determines their position. In this way, dark patches appear behind bright areas that are located closer to the source of illumination. Considering this physical interrelation, it is possible, by correlating two different kinds of extracted patches (one due to the enhanced backscattering at the hydrometeors and the other due to the strong attenuation), to identify regions in SAR–images which are affected by attenuation and enhanced backscattering effects. The differences of the backscatter coefficient for distributed targets (affected and non–affected regions) may reach values up to 15 dB.

3 Discussion of the Algorithm Steps and illustrative Application of the detection Algorithm

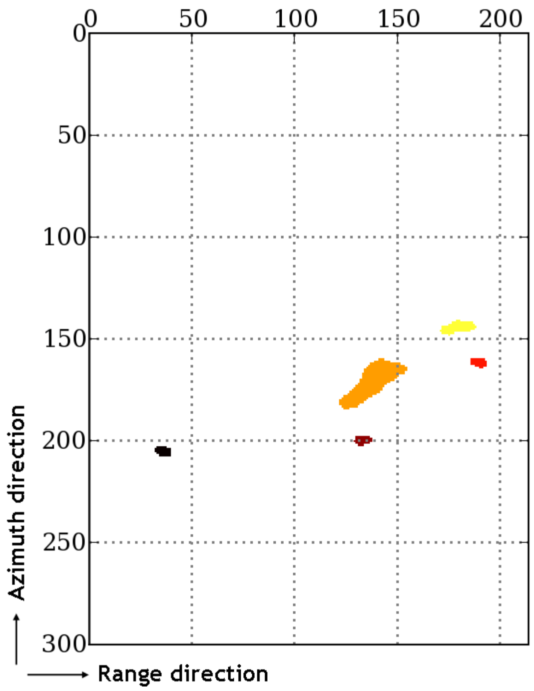
In this section the flow–chart provided in **Fig. 2** will be discussed in more detail. The input algorithm test data set can be seen in **Fig. 1**. One can easily identify the characteristic artefact features, due to heavy precipitating areas with strong backscatter coefficient (light areas) and dark patches due to signal attenuation. The first step to be executed for the identification is median filtering, which, as implied, takes the mean value of the pixel values surrounding each pixel. The kernel-size can be adjusted to the image dimensions. In our example we have chosen a box size of 5×5 pixels, where the original image has the dimensions of 300×200 pixels. See smoothed image in **Fig. 3(a)**. The reason for applying this type of smoothing is based on the fact that rain–cell signatures are larger in size than man made scatterers or local agricultural patterns. Therefore, rapidly changing signal amplitudes are smoothed and only larger patterns will emerge. Afterwards, an extraction step will be performed. The threshold levels for the detection of the cloud areas (enhanced backscattering) and the threshold levels for the attenuated areas are adjusted using a priori knowledge. The levels can be obtained from an analysis of the range power profiles.
This allows for the identification of cloud areas with higher backscatter coefficient and the extraction of the attenuated areas. By comparing the smoothed and the shadow threshold images in **Fig. 3(a)** and **Fig. 3(b)**, it can be observed, that the features have been successfully extracted. A similar observation can be made between **Fig. 3(a)** and **Fig. 3(c)**. As a subsequent step, the single objects are extracted from the threshold images.
Finally, the convolution step is performed, which accounts for the local interrelation of the enhanced backscattering and attenuation patches. The final result is shown in **Fig. 3(d)**. Areas of good correlation appear in color–coding from white to orange. Thus the algorithm has demonstrated to be useful for the identification of artefacts



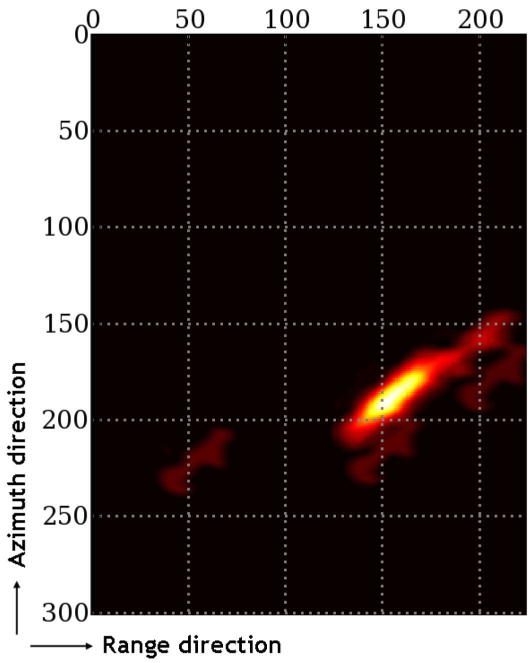
(a) Original SAR image after median filtering (box size: 5×5 pixels) termed “smoothed image” in **Fig. 2**.



(b) The black and gray “cloud”–objects are due to direct reflections from the rain region appearing as shades of white in **Fig. 3(a)**. This image is referred as “Treshold-cloud” in the flow-chart of **Fig. 2**.



(c) The colored “shadow”–objects have been isolated from **Fig. 3(a)** and are due to rain attenuated (blocked) signals from the ground. This image is referred as “Threshold”–shadow in the flow-chart provided in **Fig. 2**.



(d) Final image resulting from convolution of a single “cloud”–object with the threshold–shadow image. Areas of good correlation appear in color coding from white to orange and represents a flag for the artefacts in the original image provided in **Fig. 1**. This “signal” provides a direct phenomenological identification of propagation artefacts.

Figure 3: A summary of the processing chain detailed in the flow-chart of **Fig. 2**.

due to heavy precipitation events and can be used in order to set a flag for the enduser.

4 Conclusions and Outlook

This contribution deals with the problem of propagation effects related to the space–borne SAR imaging in general and especially in the X–band case. Attenuation due to heavy rain events has been identified as main potential reason for erroneous propagation for systems operating in the X–band frequencies.

An automated detection algorithm has been proposed which allows for an automated detection of rain–cell affected regions in SAR–images.

The disadvantage of rain features in SAR imagery may turn out to be a useful source for assessing precipitation intensity over SAR surveyed areas such as oceanic surfaces, a problem hitherto only poorly addressed.

SAR–images recorded with TerraSAR–X in combination with simultaneous measurements using a ground based weather radar of the "same" area is proposed in a further research study program.

References

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