Speckle Noise Filtering of Microwave X- Band High Resolution Spotlight Mode TerraSAR-X SAR Image

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Abstract— This paper presents a speckle filtering technique for synthetic aperture radar (SAR) image using different standard filters. SAR image is a type of radar image which can be acquired by satellite at any time; day or night, though there is a change in weather condition or heaviest rainfall. Nowadays SAR image analysis is need of the world in various fields of remote sensing. Speckle noise is the major problem in SAR images which degrades the quality of images. Because of speckle noise the analysis of the image is difficult. The speckle noise can be removed by using different types of filters. Hence the speckle noise reduction helps in preprocessing due to that the overall visibility of SAR image increases, so that processed image is much better than selected original SAR image. In the present work TerraSAR-X high resolution spotlight mode SAR image dataset having a resolution about 1m is used. In this paper, Frost, Gamma Map, Lee, Mean, Median filters is used as a speckle filter for reducing speckle noise on TerraSAR-X geotiff SAR image. The experimental result demonstrates the comparative study of all above speckle filters for improving the performance of speckle noise reduction.

Key Words— Noise Model, SAR, Speckle Filters, TerraSAR-X.

INTRODUCTION

Synthetic Aperture Radar (SAR) is an active remote sensing system, which is used to obtain high resolution images of the earth object. The SAR sensor transmitted signal information towards earth object area and measuring the scattered or reflected energy back from the target. The SAR has the capacity to penetrate smoke, clouds, fog etc. though there is change in environmental changes. The SAR system records both the amplitude and the phase of the backscattered radiation, making it a coherent imaging process like in optical system [1]. The wave reflected from the target material consists of contributions from many independent scattering points. Hence, these coherent waves results in the granular pattern of noise known as speckle. The speckle is the multiplicative noise which is the major problem in SAR images and because of such noise the resolution or quality of the image is decreased. Because of this, it is difficult to image processing on SAR images. Therefore, it is essential to remove such type of noise from SAR images [2].

There are several speckle noise reduction techniques have been developed for removing speckles and retaining edge details. The speckle reduction techniques have been studied by the several researchers & still there is no comprehensive method that takes all the constraints into consideration. The speckle noise is suppressed by applying a speckle removal filter on the digital image before use for further analysis. Zhenghao Shi et.al. [3] compare different speckle filter based on objective and practical criteria. In their experimental result, they compare acquired SAR images and computer simulated patterns. Nobuyoshi K. et.al. [4] proposed filter based on the most likelihood estimation filter. They compare the filter result with the local statistical filter. Gagnon L. et.al. [5] studied comparative result of wavelet coefficient shrinkage (WCS) filter and several standard speckle filters in the radar imaging including, Lee, Kuan, Frost, Geometric, Kalman, Gamma etc. From the results it was found that the WCS filter performs equally well as the standard filters for low-level noise and slightly outperforms them for higher-level noise. Gajanand Gupta [6] implemented improved median filter algorithm for the denoising of highly corrupted images and preservation. The result of improved median filter is compared with mean and median filter. Samuel Foucher et.al. [7] performs to analyse and evaluate the performance of a set of polarimetric SAR (PolSAR) speckle filter. Their result shows that filters performances need to be assessed using a complete set of indicators, including distributed scatterer parameters, radiometric parameters, and spatial information preservation. Masume Rahimi et.al. [8] proposed algorithm for speckle noise reduction of SAR images based on combining the hybrid mean-median filter and SRAD method and from the experimental, result they got high density, smoothing and preserving edges of SAR image.

The polarization characteristics of electromagnetic energy recorded by a remote sensing system represent an important variable that can be used in many earth resource investigations [9], [10]. It is possible to selectively send and receive polarized energy using active remote sensing systems which can be in the form of HH, HV, VH, VV polarization. In the present study TerraSAR-X Image having HH polarization is used because, like polarization shows higher reflection and is significantly different from the result observed from cross polarization [11], [12]. This paper will provide simulation model result of speckle noise reduction using NEST Version 5.0.16 software. The primary goal of speckle reduction is to remove the speckle without losing the fine details contained in an image & study comparative result of standard filters like Frost, Gamma Map, Lee, Mean and Median.

SPECKLE NOISE MODEL

In SAR sensing the data is characterized by a typical noise called speckle, which is multiplicative in nature. This is due to inherent techniques used in acquiring the reflected back signal. SAR imaging is based on the integration of a scene coherent response of

multiple scatterers from within a resolution cell. This gives rise to constructive and destructive interference of the return signal which in turn gives causes the speckle noise. Thus homogeneous regions will appear non uniform, and edges will lose their sharpness. Such data are not only visually unpleasant, but also unsuitable for image analysis such as classification, segmentation etc. Most of the noise removal techniques used in image processing field deal with additive noise which is generally present in optical data sets [13].

In practice, a digital image generated from the SAR echo returns is represented by spatial variations of pixel intensities over the area. The speckle noise model may be approximated as multiplicative and is given by,

$$A(m, n) = B(m, n) * U(m, n) + V(m, n) \quad (1)$$

Where $A(m, n)$ is the noisy pixel, $B(m, n)$ represents the noise free pixel, $U(m, n)$ and $V(m, n)$ represent the multiplicative and additive noise respectively and m, n are indices of the spatial locations. Since the effect of additive noise is considerably smaller when compared to that of multiplicative noise, (1) may be written as,

$$A(m, n) \approx B(m, n) \quad (2)$$

Hence, the better filter results are used for terrain classification, target detection and other applications [14], [15].

SPECKLE NOISE FILTER

The main objective of the present work is to provide a comparative study of TerraSAR-X SAR image with the intention to find the strength of the different approaches. In the following, the different standard filtering approaches that have been considered are listed-

a) Frost Filter-

Frost filter [16] uses an adaptive filtering algorithm which is an exponentially damped convolution kernel that adapts itself to features by using local statistics. The Frost filter differs from the Lee and Kuan filters by the fact that the image reflectivity is estimated by convolving the observed image with the impulse response of the SAR system. The impulse response of the SAR system is obtained by minimizing the mean square error between the observed image and the image reflectivity model, which is assumed to be an autoregressive process.

b) Gamma MAP Filter-

The focus of the Gamma or Maximum A Posteriori (MAP) filter [17], [18] is to minimize the loss of texture information by assuming that the image of forested areas, agricultural lands, and oceans are gamma-distributed scenes. This approach is better than the Frost filter and it uses the coefficient of variation and contrast ratios whose theoretical probability density functions will determine the smoothing process.

c) Lee Filter-

The Lee filter [19] is based on the approach that if the variance over an area is low or constant, then the smoothing will be performed. Otherwise, if the variance is high, smoothing will not be performed. The equivalent number of looks (ENL) is a parameter used to estimate noise variance and it effectively controls the amount of smoothing applied to the image by the filter. A smaller ENL value leads to more smoothing; a larger ENL value preserves more image features. In order to filter pixels located near the edges of the image, edge-pixel values are replicated. Since speckle noise in SAR images is generally assumed to be a multiplicative error model, in the Lee filter [19], the multiplicative model is first approximated by a linear model. Then the minimum mean square error criterion is applied to the linear model.

d) Mean Filter-

Mean filtering [20] is a simple, intuitive and easy to implement method of smoothing images, i.e. reducing the amount of intensity variation between one pixel and the next. It is often used to reduce speckle noise in SAR images. The idea of mean filtering is simply to replace each pixel value in an image with the mean value of its neighbours, including itself. Mean filtering is usually thought of as a convolution filter. Like other convolutions, it is based around a kernel, which represents the shape and size of the neighbourhood to be sampled when calculating the mean.

e) Median Filter-

Order-statistics filters [21], [22] are nonlinear spatial filters whose response are based on ordering (ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ranking result. Median filter is used in the SAR filters & textures program. Sometimes, to get better image quality, it may be useful to filter the same image two or three times. This filter performs better than mean filter.

STUDY AREA

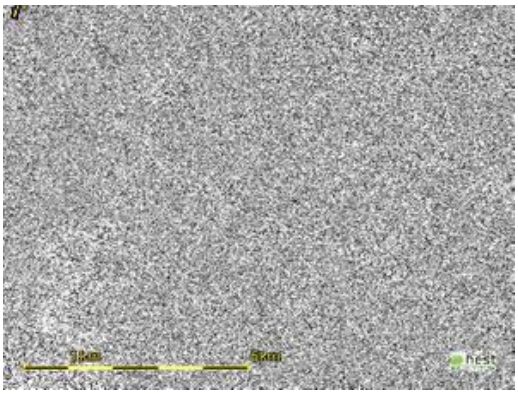

Figure 1. Original TerraSAR-X SAR Image

The study area is located in the City of Canada with latitudes 43°42′ and longitudes 79°24′ Toronto. This is a most popular city of Canada. In 2011, Toronto had a population of 2,615,060 making it the fourth most populous city in North America, after Mexico City, New York City, and Los Angeles. Toronto covers an area of 630 square kilometers, 46 kilometer long waterfront

1) [23]. The SAR image has HH polarization with incident angle 48.8. The Airbus Defense & Space provide TerraSAR-X Spot-Light-MGD, SE product dataset [24], [25]. Data processing in-

cluded radiometric calibration, geometric calibration, slant range to ground range and speckle filtering. In the present work TerraSAR-X SAR dataset is used.

SIMULATION RESULT & DISCUSSION

The speckle noise filtering is carried out for TerraSAR-X SAR image using the different standard speckle reduction filters like Frost, Gamma Map, Lee, Mean and Median filter. The simulation carried out in NEST Version 5.0.16 software. The performance all above filters in terms of sigma0 i.e. backscattering signal for HH polarization, window size 5x5, 7x7 and 9x9 is as shown in following figure,

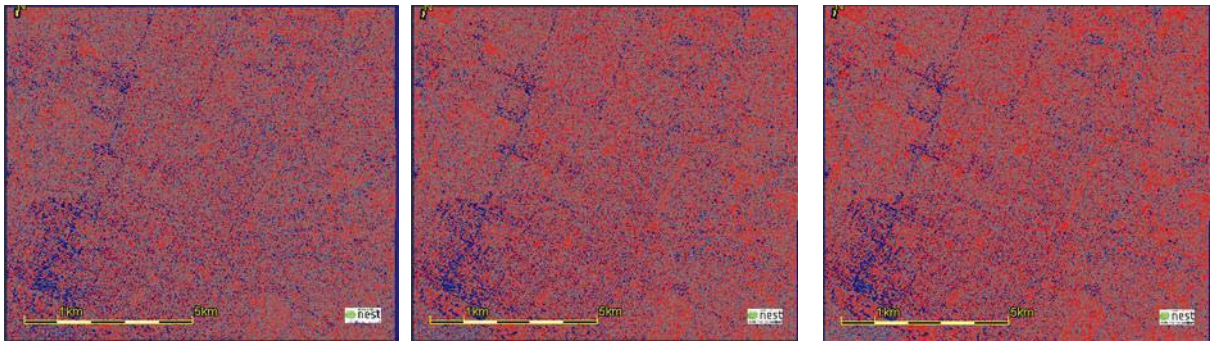

Figure 2. Frost 5x5, 7x7, 9x9

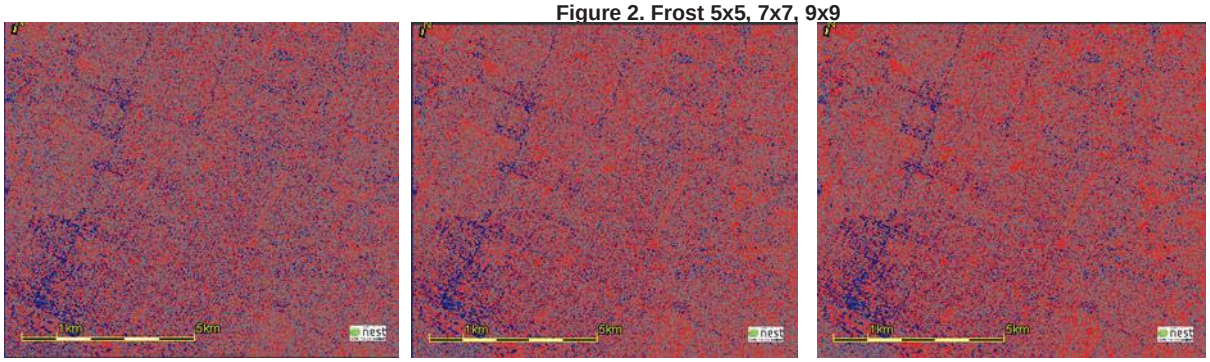

Figure 3. Gamma Map 5x5, 7x7, 9x9

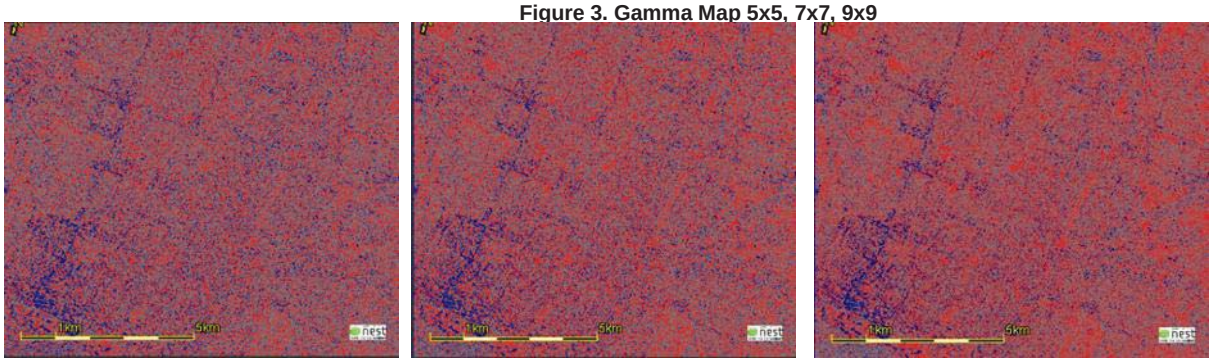

Figure 4. Lee 5x5, 7x7, 9x9

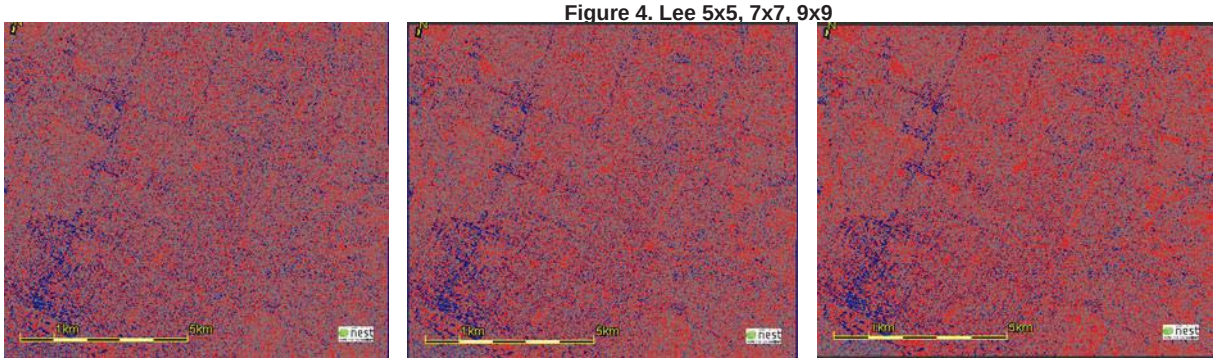

Figure 5. Mean 5x5, 7x7, 9x9

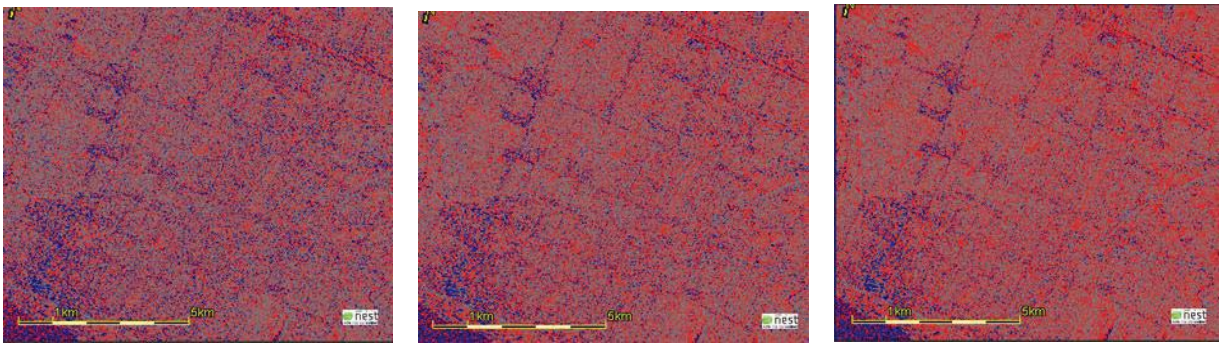

Figure 6. Median 5x5, 7x7, 9x9

From all the above figures it is found that sigma0 (dB) response and area covered by TerraSAR-X SAR image for HH polarization in the order of window size 5x5, 7x7 and 9x9 respectively. The noise reduction of Lee filter is better than Frost & Gamma Map. But from an overall result, it is found that Median filter is not only better than Mean filter, but also better than Frost, Gamma Map and Lee filter.

CONCLUSION

In this paper, speckle filtering techniques have been used to remove the speckle noise from TerraSAR-X SAR image. The primary goal of speckle reduction was achieved to remove the speckle without losing the fine details contained in an image. This paper provides the proper techniques for specific speckled noisy SAR images. The speckle noise reduction also increases as we change the window size in the order of 5x5, 7x7 and 9x9. From the simulation result, it was found that the Median filter not only better for noise reduction also better for removing blurred effect in the TerraSAR-X geotiff SAR image.

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