# Reduction of speckling noise of SAR Images using Dual Tree Complex Wavelet (DTCW) and Shearlet Transforms

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**Abstract.** The Synthetic Aperture Radar (SAR) images are difficult to interpret owing to the multiplicative speckle noise from coherent acquisition systems. Therefore, de-speckling of SAR images always plays a primary pre-processing task in SAR image processing. There are many methods using various spatial domain filters and transform domain algorithms which focus on speckle reduction but not all methods can preserve the image edge features. The article suggests a de-speckling algorithm via sparse representation using combined Shearlet Transform and DTCW transform which possess direction selectivity and shift invariant property. The experimental results, the suggested method has better PSNR, ENL, and EPI values than the existing state of art methods. The proposed methodology not only preserves the edges, also improves visual effect by enhancing the texture of SAR images.

**Keywords:** Synthetic Aperture Radar (SAR), Speckle Noise, Shearlet Transform, DTCW Transform, Sparse Coefficients.

## 1 Introduction

The SAR microwave imagery has become one of the most beneficial applications over the optical satellite symbolism on account of its capacity to work in the entire climate conditions. It has different applications, for example, namely: agriculture, remote sensing, land applications, potential applications, flood mapping, soil moisture, forestry, terrain analysis and so on [1]. SAR images obtained from Synthetic Aperture Radar are very difficult to understand and analyse because of presence of multiplicative noise called speckle noise [2]. The resolution of images is affected by the nearness of specked images. These specked images are difficult for human interpretation and hence there is a need to remove noise from SAR images. De-speckling is the pre-processing step of Automatic Target Recognition followed by detection, classification and recognition [3].

To overcome the above-mentioned drawbacks of spatial domain methods, transform domain methods were introduced. Wavelet transform is used for de-speckling of SAR images by several researchers. There is comprehensive examination of wavelet based de-speckling approaches. A wavelet transform method have better time frequency characteristics than the Fourier transform analysis and also preserves texture features and edges efficiently. The

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wavelet transform based methods cannot sparsely represent high dimensional functions [4]. To overcome the above limitation, scholars proposed many multiscale geometric transformations such as Contour let, Ridge let and Curve let Transforms. But these transforms for SAR image de-speckling blur the image edges and produce artificial images. In order to overcome the above drawbacks researchers introduced Shear let Transform which has flexible direction selectivity property [5].

### 1) Modelling of Speckle Noise

Though multiplicative clamour which is brought about by de-staged echoes from a backscattered signal is mind-boggling to demonstrate and furthermore hard to lessen . Dot is actually not a clamour but rather commotion like a granular example. The multiplicative spot clamour is as

$$Z\ (k,l) = S\ (k,l)\ N\ (k,l) \tag{1}$$

Where,*Z (k, l)*denotes the intensity format of corrupted SAR image, *S (K, l)* denotes the noise free SAR image that has to be recovered and *N (k, l)* denotes the multiplicative speckle component. The multiplicative clamour is thusly changed over into added substance commotion which is given by

$$Z\ (k,l) = S\ (k,l) + N\ (k,l) \tag{2}$$

The log change yields undesired impacts in the SAR pictures since the mean of the log-changed dot isn't zero. The proposed methodology comprises of combining Shearlet transform with Dual Tree Complex Wavelet Transform which possess both direction selectivity and shift invariance for efficient speckle reduction and extracting the sparseness of the transform coefficients to convert the denoising process into an optimization model.

## 2 Proposed Methodology

The proposed technique has been clarified in beneath algorithm. Proposed STDTCWT algorithm for noise reduction given better results than existing algorithms.

### a. Shearlet Transform

The execution of Shearlet transform is simple and flexible than multi resolution analysis transforms like Curvelet, Contourlet and Ridgelet transforms. For a 2-D signal, the Shearlet functions are,

$$A_{AB\,(\varphi)} = \{\varphi_{i,j,k(x)} = |det\ A|^{\frac{j}{2}} \varphi\left(B^{l}\ A^{j} x - k\right) \tag{3}$$

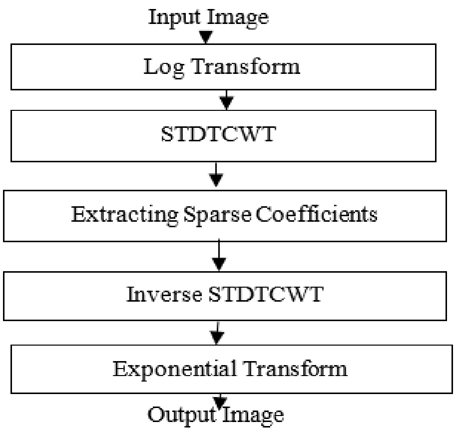



**Fig. 1.**Pipeline of the proposed methodology

where $\psi \in L^2(R^2)$, *A, B* is 2-D matrices and |detB| = 1.

Let **A** = **A**0 $=\begin{pmatrix} 4 & 0 \\ 0 & 2 \end{pmatrix}$be the anisotropic dilation matrix **B** = **B**0 $=\begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$be the shear matrix. Thewavelet functions,

$$\begin{pmatrix} \varphi_{j,l,k}^{(0)}(x)=2^{3j\backslash 2}\varphi^{(0)}(B_0^j A_0^j x-k) \\ : j\geq 0, -2^j \leq l \leq 2^j -1, k\in Z^2 \end{pmatrix} \quad (4)$$

$$SH\psi = \left\langle f, \middle| \varphi_{j,l,k}^{(d)} \right\rangle \quad (5)$$

Where, $j \geq 0$, $l = -2j \sim 2j - 1$, $\boldsymbol{k} \in Z^2$, $d = 0, 1$.

The proposed method uses the move invariant Shearlet change to accomplish SAR picture denoising dependent on meagre portrayal.

**b. DTCW Transform**

The DTCWTransform of a two-Dimensional image*(k, l)*gives anestimation of sub-band and 6-directional particular sub-groups at all level, are firmly arranged at edges $\pm 15^0$,$\pm 45^0$and$\pm 75^0$. Accordingly, the denoising must be done distinctly in the 6-directional sub-groups. After applying DTCWTransform on equ. (2), we obtain,

$$d_j^i(k,l)=x_j^i(k,l)+n_j^i(k,l) \quad (6)$$

Where, $d_j^i(k,l)$,$x_j^i(k,l)$ and $n_j^i(k,l)$ is the$(k, l)^{th}$ DTCW Transform coefficient of the log-changed watched power, the first force, and the comparing commotion segment, individually, at level *j* with direction *i*. Also, the DTCW Transform wavelet coefficients are modelled using a bivariate Cauchy PDF. For N-dimensional vector,

$$(x)=\frac{\gamma\Gamma[\frac{1+N}{2}]}{[\pi(|x|^2+\gamma^2)]^{(1+N)/2}} \quad (7)$$

gamma function $\Gamma(L)=\int_0^\infty t^{L-1}e^{-1}$dt.

## 3 Results and Discussion

The input image taken for carrying experimental results is MSTAR dataset. The performance of suggested STDTCWT technique is compared separately with the Shearlet and DTCWT transforms

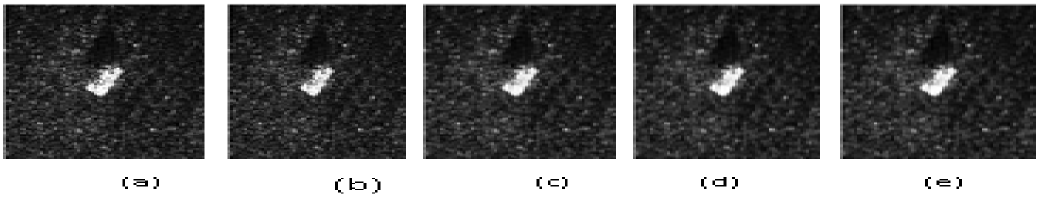



**Fig.2** (a) Input Image (b) Input Image with noise (c) De-speckled Image using Shearlet Transform (d) De-speckled Image using DTCWT (e) De-speckled Image using proposed STDTCWT

**Table1.**Performance comparison table for BRDM.

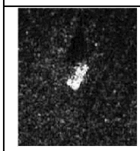
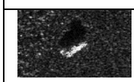
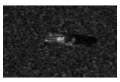
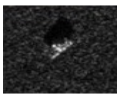
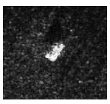
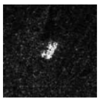
| **Input Image** | **Parameters** | **Shearlet** | **DTCWT** | **STDTCWT** |
|---|---|---|---|---|
|  BRDM 2 | PSNR | 42.6839 | 32.5079 | 44.1264 |
| | ENL | 24.1030 | 21.8284 | 24.1284 |
| | EPI | 0.9872 | 0.9321 | 0.9875 |
| | SSI | 0.7972 | 0.8701 | 0.7967 |
| | SD | 30.7696 | 31.2182 | 30.7623 |

**Table 2.** Performance comparison table for various images of MSTAR Dataset

| **Input Image** | **Methods** | **PSNR** | **ENL** | **EPI** | **SSI** | **SD** |
|---|---|---|---|---|---|---|
|  | ShearletDTCWT<br>Proposed | 36.3456<br>37.2987<br>39.5643 | 22.7865<br>23.8764<br>24.1298 | 0.9453<br>0.9234<br>0.9934 | 0.7642<br>0.7245<br>0.7124 | 30.2343<br>30.4321<br>30.1536 |
|  | ShearletDTCWT<br>Proposed | 35.5674<br>36.8976<br>39.3455 | 22.5467<br>23.3445<br>25.6785 | 0.9453<br>0.9789<br>0.9997 | 0.7678<br>0.7896<br>0.7299 | 30.4567<br>30.6789<br>30.2435 |
|  | ShearletDTCWT<br>Proposed | 36.7438<br>39.2345<br>40.2376 | 23.7864<br>24.6512<br>26.9034 | 0.9123<br>0.9123<br>0.9278 | 0.6934<br>0.6776<br>0.6100 | 29.9872<br>28.2345<br>28.1000 |
|  | ShearletDTCWT<br>Proposed | 41.5420<br>42.2563<br>43.9892 | 23.7230<br>25.9987<br>26.8719 | 0.8346<br>0.8593<br>0.8721 | 0.7256<br>0.7377<br>0.7177 | 29.4663<br>28.3678<br>27.2356 |

| | | | | | | |
|---|---|---|---|---|---|---|
|  | ShearletDTCWT | 42.6839 | 24.1030 | 0.9872 | 0.7972 | 30.7996 |
| | Proposed | 42.5079 | 21.1284 | 0.9321 | 0.8701 | 31.2182 |
| | | 44.1264 | 24.1284 | 0.9875 | 0.7967 | 30.7623 |

The performance comparison table shows that the proposed methodology gives higher PSNR, ENL and EPI values and lower SSI and SD values.

## 4 Conclusion

This work proposed a SAR Image De-speckling using combined Shearlet and DTCW transforms provide both shift invariant and directional selectivity properties. The performance of de-speckling algorithm is compared with Shearlet and DTCWT transforms. The parameters PSNR, ENL and EPI values of the proposed method are high and SSI and SD values are lesser and it is compared to existing de-speckling algorithms, results in stronger speckle-noise reduction and greater visual quality.

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