**Reply to Examiners’ Comments**

Thanh-Hai Le

28 June, 2014

**Reply to Examiner No. 1**

**Name of Student:** Le Thanh Hai

**Degree:** Doctor of Philosophy

**Thesis Title:** Scalar & Homoskedastic Models for SAR & POLSAR data

First, I would like to express my appreciation towards Examiner No. 1 for his **over-all positive comments**. I also appreciate the fact that Examiner No 1 includes not only his comments in the examiner's report, but also helpful suggestions inside the original thesis.

The examiner asked no direct question in his comments, so the following are the replies to Examiner 1’s comments as listed in the returned thesis:

|  |  |  |  |
| --- | --- | --- | --- |
| Page | Line | Grammatical Errors | Corrections |
| 4 | 5 | Missing references | Citation [51] is added in the thesis (and is shown on page 3 of this document) |
| 4 | 8 | Missing references | Citation [51] is added in the thesis (and is shown on page 3 in this document) |
| 5 | 13 | techniques … has | techniques … have |
| 6 | 5 | many fold | manyfold |
| 11 | 12 | Chapter 2 will survey | Chapter 2 surveys |
| 11 | 17 | Chapter 3 begins by by | Chapter 3 begins by |
| 14 | 5 | Assuming the number of these elementary back scatterers is sufficiently large | Assuming these elementary back scatterers are large in number and independent in nature. |
| 14 | Eq 2.1 |  |  |

***Comment:***

**Page 14: With reference to Equations 2.1, 2.2, 2.3 what are the range of *Ax*, *A* and *I?***

*Reply:*

The range of *Ax* is from, and the range of both *A* and *I* is from .

***Comment:***

**Page 14: Does the integration of pdf for *Ax; A; I* sum to 1?**

*Reply:*

With the defined range above, YES, they are all sum to 1. This is easy to verify as they belong to the classes of Normal, Chi-Squared (2 degree-of-freedom) and Exponential Distribution respectively.

|  |  |  |  |
| --- | --- | --- | --- |
| Page | Line | Grammatical Errors | Corrections |
| 15 | 6 | Missing explanation for | Explanation added |
| 15 | 12 | x,y plane | x & y plane |
| 15 | 27 |  |  |
| 16 | 2 | The parameters … are | The parameters … are: the intensity orientation angle (), the ellipticity angle () and the orientation angle () |
| 17 | 4 | machenics | mechanics |
| 17 | 28 | Missing explanation for | Explanation added |
| 20 | 28 | Font size for Eqn. 2.10 and 2.11 is different from the rest of the thesis | This is due to space restriction, where the matrix representation in the normal form font size would require a larger width than that is available in one line. |
| 33 | 18 | Eqn. [2.15) | Eqn. 2.15 |
| 34 | 10 | How did you get this Eqn? | A reference was cited for the Eqn. depicting the closed-form solution for Gamma distribution [Lopes, 1990]. The closed-form solutions for exponential and chi-squared distribution were given without citation because both are special cases of the Gamma distribution. However, the same citation is added for both Eqns. now. |
| 35 | 10 | Which distribution is more appropriate? | The most appropriate distribution is that of the "true signal", which of course, is unknown. Within the reviewed and presented models, the more appropriate ones are those that fit better with the assumed available ground-truth. This, of course, differs from one case to the next. |
| 43 | 25 |  |  |
| 76 | 24 | chapter 3 | Chapter 3 |
| 129 | 1 | chapter 5 | Chapter 5 |
| 129 | 6 | theoretical results | theoretical contributions |
| 129 | 21 | this thesis unite | this thesis unites |
| 130 | 1 | articles that has been | articles that have been |
| 132 | 14 | an important benefits | several important benefits |

**References requested by Examiner 1 (which is inluded in the thesis)**

[51] A. Lopes, E. Nezry, R. Touzi, and H. Laur. **Maximum A Posteriori Speckle Filtering And First Order Texture Models In SAR Images**. In Geoscience and Remote Sensing Symposium, 1990. IGARSS '90. 'Remote Sensing Science for the Nineties', 10th Annual International, pages 2409 --2412, May - 1990.

**Reply to Examiner No. 2**

**Name of Student:** Le Thanh Hai

**Degree:** Doctor of Philosophy

**Thesis Title:** Scalar & Homoskedastic Models for SAR & POLSAR data

I would like to thank Examiner 2 for examining the thesis carefully. I have listed the comments below, and responded to each one. I have also rectified all of the items in the errata.

***Comment:***

**Sec 1.1 and 1.2 should be reviewed again ... with proper citations on the background studies.**

*Reply:*

Both sections have been reviewed and several new citations [see below for a list of added references] are now added.

***Comment:***

**Paragraph 1 of Sec 1.3.3 should be removed or rewritten**

*Reply:*

The paragraph was removed.

***Comment:***

**The achievement of objectives should (also) be stated in the conclusion chapter.**

*Reply:*

These have now been added into the conclusion chapter on pages 130-131.

***Comment:***

**Replace the word ‘’theory" with ‘’model" throughout the thesis**

*Reply:*

This has been done.

***Comment:***

**The proposed model is derived based on the existing statistical models for SAR and extended to POLSAR… further clarifications of some key points have to be addressed and included in the thesis.**

*Reply:*

The main approach, as described in the thesis, differs in a subtle but important way. The proposed model is derived based on generic mathematical results for multi-dimensional random-walk [Goodman, 1976, Goodman, 1975].

That is, the proposed models by nature are applicable to multi-dimensional data and thus to POLSAR data. To show that the proposed (multi-dimensional) models are also applicable to SAR data, the dimension parameters in these models are collapsed into singularity (1). The thesis subsequently shows that they match perfectly with existing SAR models. This point is now re-emphasis in the thesis on page 11.

***Comment:***

**The proposed log-transform model will introduce an inevitable bias error, which may not be able to be measured by MSE.**

*Reply:*

The thesis does indicate that log-transformation will introduce bias on multiple occasions. It also shows that MSE evaluation does inherently include a bias evaluation. In fact, the thesis argues that MSE evaluation has two components: 1) bias evaluation and 2) variance valuation. For evaluating the performance of SAR speckle filters, they are translated into two criteria: 1) Radiometric preservation and 2) Noise suppression respectively (see Section 5.3).

***Comment:***

**A more comprehensive review of the relevant SAR/POLSAR speckle filters should be included.**

*Reply:*

The most recent review [3]Argenti et al., 2013 is now included together with several other publications [17]Lee et al., 1994, Cetin et al., 2000, White, 1994, Sattar et al., 1997, Wang et al., 2004, Nielsen, 2012], which are all discussed in the thesis.

***Comment:***

**Wherever possible, samples of SAR/POLSAR images with these three types of features (i.e. homogeneous, textured and strong scatterer) should be used to evaluate the effectiveness of the proposed models.**

*Reply:*

In the section on evaluating speckle filters, various different patterns have been studied [ see Section 5.3]. The patterns include: homogeneous area, several textured patterns as well as point target response.

***Comment:***

**The work done has great potential to be published in high impact factor journals such as JSTAR, IJRS and PIER.**

*Reply:*

I appreciate the Examiner's vote of confidence. Portions of the work in this thesis have been written up as academic papers and submitted for peer-review.

***Comment:***

**Define terms heteroskedastic and homoskedastic in the context of SAR imagery.**

*Reply:*

Heteroskedastic and homoskedastic are terms defined in a statistical context to respectively denote the fact that different sub-populations of given samples can have different or similar variability. In the context of SAR (and POLSAR) imagery they denote the fact that different areas in a given image can have different or similar sample variance. This is now added in the thesis on page 43.

***Comment:***

**Add references to the following statement: “for example speckle filtering, target detection, image segmentation and other cluster, classification techniques"**

*Reply:*

The references are [2]Lopez-Martinez and Fabregas, 2003, [3]Alberga et al., 2008, [4]Conradsen et al., 2003, and are now included in page 2 of the thesis.

***Comment:***

**Add references to the following statement: “most of these data processing techniques are traditionally designed for additive and homoskedastic data."**

*Reply:*

The reference is [Duch and Blachnik, 2004] and is now included in page 2.

***Comment:***

**Add references to the following statement: “Such use, however, is known to be not very robust for these so-called heavy detailed distributions."**

*Reply:*

Reference is [McElroy and Politis, 2002] and is now included in page 3.

***Comment:***

**Add references to the following statement: “it is known that such use should be avoided in preference to a ratio-based discrimination measure."**

*Reply:*

Reference is [Rignot and van Zyl, 1993] and is now included in page 3.

***Comment:***

**Add references to the following statement: “The Ordinary Least Square (OLS) is widely used as the best evaluation criteria, which is probably due to the Gauss Markov theorem."**

*Reply:*

Reference is [Furno, 1991] and is now included in page 3

***Comment:***

**Add references to the following statement: “violates the homoskedastic assumption of the theorem and thus many different ways to evaluate SAR speckle filters were proposed."**

*Reply:*

References are [Gagnon and Jouan, 1997, Argenti et al., 2013]. They are now included in page 3.

***Comment:***

**It would be easier to read and refer if all the Equations are labelled accordingly.**

*Reply:*

Originally labels were only added for equations which were deemed important or would be referred to later. Now all equations in the thesis have been updated with labels.

**Errata Sheet**

|  |  |  |  |
| --- | --- | --- | --- |
| Page | Line | Grammatical Errors | Corrections |
| Toc | - | missing page numbers | Amended |
| 1 | 13 | single SAR channel | single-channel SAR |
| 3 | 12 | Similarly speaking, | Similarly, |
| 3 | 19 | criteria | criterion |
| 4 | 14 | MMSE criteria | MMSE criterion |
| 6 | 9 | Last but certainly not least, | Thirdly, |
| 6 | 9 | such a framework allow | such a framework allows |
| 9 | 7 | multidimensional | multi-dimensional |
| 10 | 12 | The model os | The model is |
| 11 | 28 | chapter 5 | Chapter 5 |
| 12 | 6 | chapter 6 | Chapter 6 |
| 22 | 15 | RadarSat | RadarSat-2 |
| 24 | 14 | SVM | Support Vector Machine (SVM) |
| 35 | 6-7 | Rician distribution [48]... | Rician distribution [48]. |
| 35 | 11 | back scattering | backscattering |
| 36 | 10 | literatured | literature |
| 37 | 26 | proposed bu | proposed by |
| 39 | 4 | dependence | dependency |
| 44 | 27 | The nature of SAR is... heteroskedastic heterogeneously | Rephrased: As shown in the previous Section, the stochastic SAR speckle, over heterogeneous area, exhibits heteroskedastic properties. |
| 46 | 4 | most known common | most commonly known |
| 56 | 6 | POLSAR And | POLSAR. And |
| 65 | 5 | an homogeneous area | a homogeneous area |
| 77 | 3 | the objective then is | the objective is |
| 77 | 6 | Provide a reference to the source “it has already been proven…”. | The reference equation is now added: it has already been proven (see Eqn. 3.10) |
| 87 | 27 | Fig 5.6a | Fig 5.6. |
| 89 | - | Figure 5.6 - subtitle (a) - remove the caption “(a)” | (a) is removed |
| 91 | - | Figure 5.8: Legends are too small to read | Legends have been enlarged. |
| 95 | - | Figure 5.12 – Use the same scale for y axis (i.e MSE 0:1) across all the plots. | The same scale is now used for y axis (i.e MSE 0:0.8) across all the plots. |
| 103 | 22 | related to the ENL index. over | related to the ENL index. |
| 104 | 14 | Equation 5.3.2.1 – incorrect numbering of equation | The number is corrected to Eqn. 5.11 on page |
| 109 | 8 | Figs. 5.21c and 5.21d allows | Fig 5.21(a) and Fig 5.21(d) allow |
| 112 | 13 | these smaller requirements | these requirements |
| 132 | 9 | evaluation criteria | evaluation criterion |

**References requested by Examiner 2**

[10] Alberga, V., Satalino, G., and Staykova, D. K. (2008). **Comparison of polarimetric SAR observables in terms of classification performance**. *International Journal of Remote Sensing*, 29(14):4129-4150.

[Argenti et al., 2013] Argenti, F., Lapini, A., Bianchi, T., and Alparone, L. (2013). **A tutorial on speckle reduction in synthetic aperture radar images.** *Geoscience and Remote Sensing Magazine, IEEE*, 1(3):6-35.

[Cetin et al., 2000] Cetin, M., Karl, W. C., and Castanon, D. A. (2000). Evaluation of a regularized sar imaging technique based on recognition-oriented features.

[Conradsen et al., 2003] Conradsen, K., Nielsen, A., Schou, J., and Skriver, H. (2003). **A test statistic in the complex Wishart distribution and its application to change detection in polarimetric SAR data.** *IEEE Transactions on Geoscience and Remote Sensing*, 41(1):4 -19.

[Duch and Blachnik, 2004] Duch, W. and Blachnik, M. (2004). **Fuzzy rule-based systems derived from similarity to prototypes.** In Pal, N., Kasabov, N., Mudi, R., Pal, S., and Parui, S., editors, *Neural Information Processing*, volume 3316 of *Lecture Notes in Computer Science*, pages 912-917. Springer Berlin Heidelberg.

[Furno, 1991] Furno, M. (1991). **Comparison of estimators for heteroskedastic models.** *Journal of Statistical Computation and Simulation*, 38(1):99 - 107.

[Gagnon and Jouan, 1997] Gagnon, L. and Jouan, A. (1997). **Speckle filtering of SAR images - A comparative study between complex-wavelet-based and standard filters.** In *Proceedings of The Society of Photo-optical Instrumentation Engineers (SPIE)*, volume 3169, pages 80-91.

[Goodman, 1975] Goodman, J. W. (1975). **Statistical properties of laser speckle patterns.** In *Laser Speckle and Related Phenomena*, volume 9, pages 9-75. Springer Berlin / Heidelberg.

[Goodman, 1976] Goodman, J. W. (1976). **Some fundamental properties of speckle.** *Journal of the Optical Society of America*, 66(11):1145-1150.

[Lee et al., 1994] Lee, J. S., Jurkevich, L., Dewaele, P., Wambacq, P., and Oosterlinck, A. (1994). **Speckle filtering of synthetic aperture radar images: A review.** *Remote Sensing Reviews*, 8(4):313-340.

[Lopez-Martinez and Fabregas, 2003] Lopez-Martinez, C. and Fabregas, X. (2003). **Polarimetric SAR speckle noise model.** *Geoscience and Remote Sensing, IEEE Transactions on*, 41(10):2232-2242.

[McElroy and Politis, 2002] McElroy, T. and Politis, D. N. (2002). **Robust inference for the mean in the presence of serial correlation and heavy-tailed distributions.** *Econometric Theory*, pages: 1019-1039.

[Nielsen, 2012] Nielsen, F. (2012). **K-mle: A fast algorithm for learning statistical mixture models.** In *Acoustics, Speech and Signal Processing (ICASSP), 2012 IEEE International Conference on*, pages 869-872.

[Rignot and van Zyl, 1993] Rignot, E. and van Zyl, J. (1993). **Change detection techniques for ERS-1 SAR data.** *IEEE Transactions on Geoscience and Remote Sensing*, 31(4):896 - 906.

[Sattar et al., 1997] Sattar, F., Floreby, L., Salomonsson, G., and Lovstrom, B. (1997). **Image enhancement based on a nonlinear multiscale method.** *Image Processing, IEEE Transactions on*, 6(6):888-895.

[Wang et al., 2004] Wang, Z., Bovik, A., Sheikh, H., and Simoncelli, E. (2004). **Image quality assessment: from error visibility to structural similarity.** *Image Processing, IEEE Transactions on*, 13(4):600-612.

[White, 1994] White, R. G. (1994). **Simulated annealing algorithm for SAR and MTI image cross section estimation.** *Proc. SPIE*, 2316:137-145.

**Reply to Examiner No. 3**

**Name of Student:** Le Thanh Hai

**Degree:** Doctor of Philosophy

**Thesis Title:** Scalar & Homoskedastic Models for SAR & POLSAR data

**I would like to thank Examiner No. 3 for the constructive comments and suggestions. Since these were presented in the order of the thesis' chapters, my responses below will follow this sequence:**

**1. Overall Organization and presentation**

***Comment:***

**The presentation needs to be considerable improved.**

**For example, Chapter 3 and 4 talks about models, but these models were not organized into sections with appropriate headings ... (see my comments in the respective chapter below).**

*Reply:*

I greatly appreciate the Examiner’s suggestions in making this thesis a better and improved version!

The presentation has been improved according to the Examiners' suggestions. These changes are as detailed below.

***Comment:***

**Page ii of the Contents section is missing**

*Reply:*

Page numbers have been added for the Contents section on pages (ii) to (xv)

***Comment:***

**Usually, a Glossary is put at the end of the document**

*Reply:*

The Glossary section is now placed at the end of the thesis, starting from page 152.

***Comment:***

**Why are some page numbers (ii,iii ... ix,xi) missing?**

*Reply:*

They were missing due to slight different in behaviour in Latex systems on Windows and Linux. A fix has been applied to ensure consistent behaviour and the page numbers are now printed out correctly as shown in pages (ii) to (xv)

***Comment:***

**Page xiii: List of source codes. These are actually pseudocodes and not source codes.**

*Reply:*

The description is now changed to “List of Pseudocodes"

**2. Abstract**

***Comment:***

**Since these models are the key contributions of the thesis, it would be good to give a separate name to each of these models. Also a short description of what each of them is suitable for should also be included in the abstract.**

*Reply:*

The models' names and descriptions are summarised here as follows:

* The determinant () & log-determinant models (): are the statistical models for the determinant of the POLSAR covariance matrix and its log-transformed version.
* The determinant-ratio () & the log-distance () models: In cases where the underlying signal () is assumed to be available, statistical models for these observables are shown to be consistent (i.e. independent to ). Thus these observables are excellent options to measure the distance between a given POLSAR covariance matrix and a given ground-truth.
* The dispersion () & the contrast () models: in cases where the underlying signal () is not available, these more elaborated observables also have consistent statistical models. They can be used to measure the distance from a given POLSAR covariance matrix and a given group of the same thing.

A concise description of the above has been added into the abstract.

***Comment:***

**The abstract lists the benefits of these models but not the shortcomings. Why?**

*Reply:*

The shortcomings were discussed in the final chapters of the thesis (section 6.2.2). They have also been included in the abstract now (page v).

**3. Chapter 1**

***Comment:***

**Table captions appears at the top of a table, rather than below it**

*Reply:*

This is typical of IEEE publications, so we adopted it in the thesis. However we tried this stylistic suggestion and it looks good, so it has been adopted for the revised thesis.

***Comment:***

**No references throughout this chapter.**

*Reply:*

References have been included in this chapter (as shown on pages 2,3 …), hence increasing its persuasive power.

***Comment:***

**You are trying to propose an additive and homoskedastic model for the data. What makes you think that this model is appropriate?**

*Reply:*

Before an answer is laid out, I wish to make a few points. Firstly, I do think that the Examiner has raise a good and important question here. However the models are, at the end of the day, judged mainly by their performance in practice. In turn, the performance is found from the outcome of various experimental evaluations and after developing some mathematics. But the experiments and mathematics require quite a lot of theoretical explanation and background discussion before they are presented - and this is what forms the main bulk of the thesis. Because of this necessary sequence, I don't think that the demonstration of the models appropriateness can be tackled in the very first chapter, although the thesis can (and does) reveal early on that the models will (later) be shown to work well.

To directly address the Examiner's concern, I’d like to emphasize a few points that have been noted earlier in the thesis. First, the generic model proposed in this thesis is applicable to multi-dimensional POLSAR data. Second, when the multi-dimensional data is collapsed into one dimension, the specific case of the proposed model matches perfectly with the model proposed for SAR by Arsenault [Arsenault and April, 1976]. Thus - even before performing a detailed evaluation - there is good evidence that the proposed generic model is at least as appropriate as the widely-accepted model cited above. This discussion is now included in the revised thesis, starting on page 11.

***Comment:***

**In section 1.4, it may be worthwhile to mention that the author's contribution had been published in various venues, together with a list of author's publications.**

*Reply:*

The list of publication is now included in this section as well, as shown on page 11.

**4. Chapter 2**

***Comment:***

**Perhaps the theory section can be moved to a separate chapter, so that more space can be dedicated to the discussion of related work**

*Reply:*

I have consider the examiner’s suggestion, but in the end I could not move the theory section away from a discussion of related work, because so much of the theory comes from the related work (i.e. it is not possible to cleanly separate these topics). But actually I believe the examiners request is really that "more space can be dedicated to the discussion of related work". So instead I heavily updated the chapter to do exactly what the examiner requests. For example:

1. Section 2.1 (basic theory about the data and older related work) is shortened to 12 pages (from 14 pages) and
2. Section 2.2 (newer related work and extended theory) is now extended significantly to 17 pages (from 15 pages).

I believe that this rewriting leads to a better balance between describing the nature of the data and reviewing the related work.

**5. Chapter 3**

***Comment:***

**How can the statement on page 44 line 1 “... intensity are equal to a scaled version of these unit variables, specifically and ” be true?**

*Reply:*

The statement in page 44 line 1 should be interpreted strictly in the context that precedes it. Mathematically speaking, is just a constant, which makes the statement true. Any resemblance of this to the SAR signal will only be established in the next paragraph onwards. In fact, line 7 page 44 clearly indicates under what circumstances that can be considered constant (namely across spatially homogeneous areas).

***Comment:***

**Why homoskedasticity is valid, and what are the assumptions in this analysis?**

*Reply:*

Spatial homogeneity is the assumption used in the analysis thus far. Its limitation is acknowledged in the very next sentence, as the Examiner No. 3 pointed out: “Over heterogeneous areas, … varies significantly ...”. This assumption is actually not very restrictive. It should be noted that at the level of each physical radar resolution cell, the value measured in SAR is not deterministic. For all practical purposes, the single measured value is considered to be the result of a stochastic process, which has one “true" signal (i.e. ). In that sense, the assumption (of a single stochastic process) is actually applicable to both homogeneous and heterogeneous areas.

***Comment:***

**If is not a constant, then *var*() and *var*() cannot be homoskedastic**

*Reply:*

If the imaging area is heterogeneous, then is no longer a constant from one resolution pixel to the next. That much is clear. Then, as reviewed in Section 2.2, there are many different ways to model *,* which in turns leads to many different models for the observable magnitude. This non-constant also leads to heteroskedasticity, should we consider “*var*() and *var*()" as the variation of the observables in an area. And the Examiner correctly pointed out in his comment.

However, if we consider “*var*() and *var*()" as the deviation of the observables from their corresponding “true signal" at each physical resolution cell level, then is constant at each resolution pixel!

Consequently *var*() and *var*() will be independent of (as described in Table 3.3). In fact they are constant, which leads to homoskedasticity!

***Comment:***

**If there are different models, the author should give a name to each of his models ...**

*Reply:*

Yes there are several models proposed and the thesis has been updated with names for each of them, which can be found in sections 3.4 and 4.3.

**6. Chapter 4**

***Comment:***

**When you have highly correlated data (i.e. homogeneous areas), the determinant will be very small, leading to a very narrow PDF in Equation 4.1. Also the inverse is ill-defined, leading to large errors in your model.**

**Please justify the situations, if any, your model will not work well.**

*Reply:*

Equation 4.1 is the PDF for the circular complex Gaussian distribution, which is widely used in POLSAR. Its form, as shown in equation 4.1, is written as:

This equation is also ill-defined when = 0, which is also the same time that is ill-defined. In other words, the proposed model has the same assumption and validity of the widely-accepted circular complex Gaussian distribution model. In POLSAR, = 0 most commonly happens when the dataset is in Single-Look format. Actually, this restriction is clearly stated in the sentence that follows Equation 4.1: “the covariance matrix is only defined on multiple data-points".

In fact, it was partially for the “narrow PDF and large errors" concern that the use of log-transformation is proposed. Since the original domain is multiplicative, the range of small values is, as also observed by Examiner No. 3, commonly found to be extremely limited (ranges from 0+ to 1). The log transformed domain not only changes the nature of the noise from multiplicative to additive, but also give this “small" range (0*;* 1) a much wider space. In other words, it helps to expand the “narrow" distribution depicted in Equation 4.1 (when is small) to become another distribution whose shape does not depend on, as depicted by the Equation below:

***Comment****:*

**On page 66, 3*rd* paragraph, last sentence, the author declares that “A visual match is clearly observable ...". However, in Fig 4.2(a) ...**

*Reply:*

I understand that the Examiner is concerned about the subjective quality of the “visual match" claim. Because of this, the section has now been updated so that every `visual match' is further supported by high significance level (or p-value) in the standard Kolmogorov-Smirnov goodness-of-fit test between histograms [Kolmogoroff 1941], noted under each graph. While a good p-value may not lead to automatic acceptance of the model, consistently high p-values lend a high level of confidence to the proposal.

***Comment:***

**In fact, at x-axis value, the real data has a value that is a sharp dip from its neighbouring values. Perhaps, it is important to explain why the real data behaves in such a way?**

*Reply:*

It is observable that the chart for the real data (AIRSAR case) does not exhibits as good behaviours in comparison to other dataset (e.g. RADARSAT2 or simulated data). This is because the AIRSAR data set is much smaller in size than the other dataset (50x50 for AIRSAR vs. 300x300 for RADARSAT2). Naturally, real data sets have natural fluctuation in comparison to perfect theoretical assumptions, (e.g. the area is assumed to be homogeneous while such a fact is not known for sure, in practice). In small dataset (i.e. the AIRSAR dataset) these imperfect fluctuations are expected to be more pronounced than others.

***Comment:***

**The section heading 4.5.3 should be “Effective Number-of-Looks" instead of “Effect Number-of-Looks"**

*Reply:*

The header is now changed to “Effective Number-of-Looks”

**7. Chapter 5**

***Comment:***

**Page 94, section 5.2.2.2 MSE is first used here. What is MSE? Is it Mean Squared Error? If yes, what is the reference value for calculating the MSE?**

*Reply:*

MSE does stand for Mean Squared Error, and this is updated accordingly on page 92 in the thesis. The reference for computation in the section is the “true signal”.

***Comment:***

**Fig 5.11 shows two curves that are almost, if not exactly the same. ... What is the difference between them?**

*Reply:*

Fig. 5.11 shows two curves that are essentially the same. One of them is “simulated result" and the other is “analysis formula". The difference is that the former is computed through a Monte-Carlo simulation and the other is a simple plotting of the mathematical calculated values. The purpose is to show that the heuristic formula given as

closely tracks observable values. The above clarification is now presented in a much more detailed manner on page 92 in Section 5.2.2.2.

***Comment:***

**Fig 5.12: shows the MSE and speckle suppression power of your f-MLE filters for homogeneous area. How does it compare with the other state-of-the-art speckle filters?**

*Reply:*

It should be noted that the f-MLE filters are iterative filters, where the number of iterations is configurable. Thus assuming prior knowledge of a homogeneous area, by increasing the iteration number, the speckle suppression power can be improved arbitrarily. But of course, such knowledge is only theoretical and may be difficult to obtain for real-life scenarios.

Concerning the comparison with other state-of-the-art filters, please refers to the reply for comment related to Fig 5.15.

***Comment:***

**Please label the two curves in Fig. 5.13**

*Reply:*

The labels have now been added to figure 5.13 as shown on page 97.

***Comment:***

**In Fig 5.15 you show a comparison between f-MLE filter and the box-car filter for heterogeneous patterns ... I am still curious about how f-MLE filter will compare with other state-of-the-art filters for heterogeneous area as well.**

*Reply:*

While I am eager to demonstrate and to prove the good results of my proposed f-MLE filter in a rigorous manner, I have decided not to include this in section 5.3 where the performance of many different filters are reviewed. There are a few reasons for such a decision. First, the focus of section 5.3 is to propose a new way to evaluate speckle filters, **not** to propose any new speckle filter. Instead of discussing the performance of one particular filter (f-MLE), I wish to focus more exclusively on the topic of *how* to evaluate such filters. Second, assuming the performance of the f-MLE filter is included and found to be superior to others, then such a result would be highly suspect because I would in effect be proposing both a speckle filter as well as a new approach to evaluate speckle filters. As much as possible, I would like to keep these issues independently of each other. Last but not least, as noted by all Examiners and myself (in the thesis abstract, introduction and conclusion), speckle filtering is not the main topic of the thesis. It is only one avenue to demonstrate the benefits of the proposed models for SAR & POLSAR data.

***Comment:***

**Look at Fig 5.13 again, ... can I assume that (b) and (d) are the results of the boxcar filter for homogeneous area? Can these results be compared to the f-MLE results for homogeneous area in Fig 5.12?**

*Reply:*

Yes, Fig 5.13 shows the results of applying the boxcar filter on two homogeneous areas that are 3dB apart. The purpose of Fig 5.13 is to illustrate how AUC (i.e. Area Under the Curve) and MSE can be used to evaluate the performance of speckle filters on heterogeneous area. Thus, what it shows is not to be taken for comparison with what is shown in Fig. 5.12. On a related note, Fig. 5.15 shows a comparison between the result between boxcar and f-MLE filters over various underlying patterns.

**8. Chapter 6**

***Comment:***

**If the proposed models are “far from complete", how can it be an accurate representation of the data.**

*Reply:*

The proposed models in this thesis do not aim to become accurate representations of all data, or to be fully representative of all data. Rather, they are proposed as being highly representative (and possibly the *most representative* scalar models) for the multi-dimensional POLSAR data. Despite not being perfect, the models are very useful, since scalar models are often needed when scalar decisions are required, for example, in answering commonly asked questions such as: “what is the best speckle filter for the given data set?”, “what type of surface does the region of interest belong to?”, etc. These points have now been added to the thesis (on page 135) to clarify the statement concerned.

***Comment:***

**Page 133, line 3: “it is definitely not fully representative of the data.". So what kind of error it cause? How will it affects the use of your model?**

*Reply:*

Since the full data is multi-dimensional and the proposed models are scalar, the proposed models inherently suffer from loss of dimension This restricts the use of the model to a class of problems where a single scalar decision, ranking, sorting or classification answer is required for the complex dataset. They, however, are the most practical way to answer the types of question noted above. On the other hand, the proposed models might not be very useful in applications where the relationship among each component of the multi-dimensional data is used to make further inferences.

***Comment:***

**Page 133, line 1: “... its potential still mostly stays undiscovered". So what have you done with your thesis? Do 10% of the work and leave the other 90% for other people to do it for you? A thesis is supposed to persuade others to believe what you have proposed and to use it. How can you expect others to believe in you, when you don't know what most of what it is supposed to do?**

*Reply:*

This thesis tries to maintain and follow a very rigorous scientific methodology in order to convince others that the proposed approach is theoretically sound. This includes theoretical mathematical transformations and hypothesis-testing experiments. The theory, mathematics, objective analysis and subjective evaluations all agree, and demonstrate the validity of the models. To show that the theoretical models are also applicable in practice, the thesis also includes a chapter detailing several different applications for the proposed models, but with the disclaimer that the examiner has taken exception to.

To explain this, firstly it is completely impossible for one thesis to include a discussion on *all possible uses* of something as general as a model such as this. Therefore, the thesis concentrates on what are likely to be the most important uses. These also happen to coincide with the applications that the author was working on when he originally derived the models. Secondly, if other researchers find these models to be useful, they will apply them in many different situations. Maybe more than we can imagine at present. Therefore it is only being honest to acknowledge this fact in the thesis.

Actually, there are two questions involved. The first question is: “should the proposed models be taken as true”. And the second question is “what else can the proposed models be used for?”. They are not necessarily related. In summary, the thesis contains a thorough investigation of the models, and presents results that are both consistent, positive and indicative. This should be highly persuasive. At the same time, the thesis makes an effort to evaluate the application of the models in the most important usage domains that the author has identified, as well as to address the use of the models beyond that.

Nevertheless, to remove the potential confusion by the statement concerned, the sentence is now being rephrased as follows and can be found on page 136.

“Building up from the proposed models, several possible future work has been identified.”

***Comment:***

**On page 10, Chapter 1, the author specified a list of “results to be obtained". However, in the conclusion chapter, there is no corresponding list of achievements...**

*Reply:*

A corresponding list of achievements has been included in the conclusion which can be found on page 130-131, showing that all objectives are met.

**9. Appendix**

***Comment:***

**It is not usual to attach copies of academic papers in the Appendix.**

*Reply:*

They were included for the convenience of the examiners and other readers. They have now been removed from the Appendix.

**References for Examiner 3**

[Arsenault and April, 1976] Arsenault, H. H. and April, G. (1976). **Properties of speckle integrated with a finite aperture and logarithmically transformed.** *Journal of the Optical Society of America*, 66(11):1160{1163.

[Kolmogoroff 1941] A. Kolmogoroff, “**Confidence limits for an unknown distribution function,**” The Annals of Mathematical Statistics, vol. 12, no. 4, pp.461–463, 12 1941. [Online]. Available: http://dx.doi.org/10.1214/aoms/1177731684