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Clutter Effects on the Interferometric Phase of Ground Moving Targets

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Abstract

This report mainly investigates the clutter contamination problem for a two-channel radar system using both simulated and realistic clutter (measured airborne data). The objective of this study is to show the clutter effects on the interferometric phase of simulated moving targets using different simulation scenarios and to investigate the reasons for the biases in the measured ATI phase angles of the moving targets. Simulations show that not only the clutter power affects ATI phase estimation but also a slight variance in supposedly very similar clutter distributions can have a significant effect on ATI phase measurements.

Different target behaviors like targets with varying magnitudes over time and accelerating targets are also analyzed in the rest of the report. Theoretical results are evaluated and illustrated with simulations.

Résumé

Le présent document étudie le problème de contamination par le clutter d’un système radar à deux canaux à l’aide de clutter simulé et du clutter réaliste (données aéroportées mesurées). L’étude a pour but de montrer les effets de clutter sur la phase interférométrique des cibles mobiles simulées au moyen de différents scénarios et de déterminer les raisons des erreurs qui se produisent lors de la mesure des angles de phase ATI des cibles mobiles. D’après les simulations, non seulement la puissance du clutter a une incidence sur l’estimation de la phase ATI, mais aussi une faible variance dans des distributions de clutter théoriquement très similaires peut avoir un effet considérable sur les mesures de la phase ATI.

Le comportement de différentes cibles, comme des cibles dont la grandeur varie dans le temps et des cibles en accélération, est analysé dans le reste du rapport. Une évaluation des résultats théoriques a été effectuée, appuyée par des simulations.

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Executive summary

In a two-channel synthetic aperture radar system, there are several SAR-GMTI techniques to suppress the clutter and measure the target motions. One of these SAR-GMTI techniques which will be used by RADARSAT-2 MODEX mode, is along-track interferometry (ATI). The SAR interferogram which is used to estimate the target's across-track velocity is defined as the product of the first channel and the complex conjugate of the second channel.

For two-channel along-track interferometry (ATI), the measured differential phase may be contaminated by the overlapping stationary clutter, leading to errors in velocity and position estimates. This report mainly investigates the clutter contamination problem for a two-channel radar system using both simulated and realistic clutter (measured airborne data). The clutter effects on the interferometric phase of simulated moving targets using different simulation scenarios have been demonstrated and the reasons for the biases in the measured ATI phase angles of the moving targets have been investigated. Simulations show that not only that the clutter power affects ATI phase estimation but also that a slight variance in supposedly very similar clutter distributions can have a significant effect on ATI phase measurements.

Different target behaviors like targets with varying magnitudes over time and accelerating targets are also analyzed in the rest of the report. Theoretical results are evaluated and illustrated with simulations. Varying RCSs of the moving target over time do not have any significant effect on the ATI phase. That shows us that the target magnitude does not have any effect on the ATI phase as long as there are no extended gaps in the reflectivity. The target acceleration in the across-track direction a_{y0} has a significant effect on the ATI phase. Neglecting the contributions of a_{y0} to the ATI phase can give erroneous estimates.

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Sommaire

Dans un système radar à antenne synthétique (RAS) à deux canaux, plusieurs techniques RAS-GMTI sont utilisées pour supprimer le clutter et mesurer le mouvement des cibles. L'une de ces techniques, qui sera utilisée dans le mode MODEX de RADARSAT-2, est l'interférométrie longitudinale (ATI). L'interférogramme RAS qui sert à estimer la vitesse longitudinale d'une cible est défini comme étant le produit du premier canal et le conjugué complexe du second canal.

Dans l'interférométrie longitudinale (ATI) à deux canaux, la phase différentielle mesurée peut être contaminée par du clutter stationnaire chevauchant, ce qui peut entraîner des erreurs d'estimation de la vitesse et de la position. Le présent rapport étudie principalement le problème de contamination par le clutter d'un système radar à deux canaux au moyen de clutter simulé et de clutter réaliste (données aéroportées mesurées). Les effets du clutter sur la phase interférométrique de cibles mobiles simulées ont été démontrés à l'aide de différents scénarios, et les raisons des erreurs qui se produisent lors de la mesure des angles de phase ATI de ces cibles ont été étudiées. D'après les simulations, non seulement la puissance du clutter a une incidence sur l'estimation de la phase ATI, mais aussi une faible variance dans des distributions de clutter théoriquement très similaires peut avoir un effet considérable sur les mesures de la phase ATI.

Le comportement de différentes cibles, comme des cibles dont la grandeur varie dans le temps et des cibles en accélération, est analysé dans le reste du rapport. Les résultats théoriques ont été évalués et illustrés au moyen de simulations. Une fluctuation de la SER dans le temps n'a pas d'effet significatif sur la phase ATI. Cela montre que la grandeur de la cible n'a pas d'effet sur la phase ATI, tant et aussi longtemps qu'il n'y a pas d'écart étendu de la réflectivité. L'accélération de la cible dans la direction longitudinale a_{y0} a un effet considérable sur la phase ATI; par conséquent, il faut tenir compte des contributions de a_{y0} à la phase ATI, sinon cela pourrait fausser l'estimation.

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The authors would like to thank all the RADARSAT-2 GMTI group members for their help and providing an enjoyable environment during this visit.

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1. Introduction

Canada's RADARSAT-2 commercial SAR satellite will have an experimental operating mode that will allow ground moving target indication (GMTI) measurements. This mode is called MODEX (Moving Object Detection Experiment) [1]. It will provide the first opportunity to routinely measure and monitor vehicles moving on the earth's surface from space. The RADARSAT-2 SAR antenna design allows the antenna to be partitioned into two halves along the direction of flight and thus permits two closely spaced observations to be made of the same scene to observe temporal changes [2].

In a two-channel synthetic aperture radar system, there are several SAR-GMTI techniques to suppress the clutter and measure the target motions. One of these SAR-GMTI techniques which will be used also by RADARSAT-2 MODEX mode is along-track interferometry (ATI). The SAR interferogram which is used to estimate the target's across-track velocity is defined as the product of the first channel and the complex conjugate of the second channel.

For stationary terrain the two perfectly balanced channel signals are identical and can be canceled out (clutter suppression) by computing the phase difference, i.e. the interferogram, whereas the moving targets remain in the differential data [3]. It can be shown that a moving target with a slant range velocity ν_r causes a differential phase shift $\varphi_I = 4\pi\nu_r\tau/\lambda$ (τ is the time between two observations and λ is wavelength), which may be detected by interferometric combination of the signals from a two-channel along-track SAR system [4]. For two-channel along-track interferometry (ATI), the measured differential phase may be contaminated by the overlapping stationary clutter, leading to errors in velocity and position estimates. In order to accurately estimate the target's true velocity, clutter contamination of the signal must be minimized [5]. Precise knowledge of the interferogram's phase and amplitude statistics is very important for distinguishing the moving targets from the clutter.

There have been several studies on the clutter effects on the intended signals. As a special case, the researchers of the Spase Based Radar Group at DRDC Ottawa have investigated (e.g. [3, 5-8]) and are still investigating the effects of the clutter on the interferometric phase of the moving targets and trying to find solutions to minimize them.

Effects of stationary clutter on a moving target's interferometric phase have been reported previously [6], showing that the phase is dependent on the signal-to-clutter ratio (SCR) [7]. It has also been shown both theoretically and experimentally that the interferometric phase is a function of the target's broadside time offset and the difference between the target raw-signal length and the match filter length [8]. When coupled with a large along-track velocity component of the target, these differences may amount to 0.2 to 0.3 radians biases in the measured interferometric phase. There remain still many unanswered questions such as how to reliably estimate the target's true interferometric phase from the measured SCR. In a nonhomogeneous terrain, the degree of physical overlap of the target with a bright stationary point clutter may also influence the estimation accuracy.

This report investigates the clutter contamination problem for a two-channel radar system using both simulated and realistic clutter (measured airborne data). The objective of this study is to show the clutter effects on the interferometric phase of simulated moving targets using different simulation scenarios and to investigate the biases in the measured ATI phase angles of the moving targets.

2. The effects of real clutter on simulated targets

2.1 Slant range equation for a target with constant velocity

In the simulations of the first two sections (sections 2 and 3), we assume that a target travels with constant velocity and no acceleration. Without acceleration, the slant range distance from the reference antenna to the moving target at any time can be expressed as

$$R(t)= \sqrt{(x_o+(v_x-v_a)t)^2+(y_0+v_y t)^2+H^2}\ , \qquad (1)$$

where x_0 is the azimuth location and y_0 is the range location at time $t=0$, v_x and v_y are azimuth and range velocities of the target and radar has a velocity v_a at a fixed altitude H.

Approximating (1) by a second order Taylor series around broadside-time t_b [9], we have

$$R(t)= R_b+ v_s(t - t_b)+ \frac{v_{rel}^2}{2R_b}(t - t_b)^2\ , \qquad (2)$$

where $v_s=\alpha v_y$, $v_{rel}^2 = (v_x-v_a)^2 + (1- \alpha^2) v_y^2$, $\alpha = y_b/R_b$ and the broadside distance R_b can be expressed as [9],

$$R_b = \sqrt{(y_0-v_y t_b)^2+H^2} = \sqrt{y_b^2+H^2}\ . \qquad (3)$$

2.2 Radar and airborne geometry parameters

Simulations were carried out using deterministic point targets moving with velocity of v_x=12 m/s and v_s=4 m/s at the same range position during the observation time. Ideal (non-fading) target signals that are spatially smaller than a resolution cell were created and inserted into each channel. A real airborne SAR data set acquired by Environment Canada's CV580 C-Band SAR configured in its along-track interferometric (ATI) mode [10], was used as the background clutter.

A list of radar and airborne geometry parameters belonging to Environment Canada's CV580 C-Band SAR which are used in the simulations is provided in Table 1.

*Table 1. **Radar and geometry parameters for CV580 data collection on 5 November 2000.***

Parameter	**Value**
Carrier frequency (C-band)	5.30 GHz
Wavelength (λ)	0.0565 m
Range at broadside (R_o)	10 km.
3 dB antenna beamwidth (β)	3^o
Physical antenna separation distance (d)	0.54 m.
Pulse repetition frequency (PRF)	668.2 Hz.
Aircraft velocity (v_a)	130 m/s

Fig. 1 shows the SAR image of the test site indicating different regions selected as test clutter areas (1 to 4).

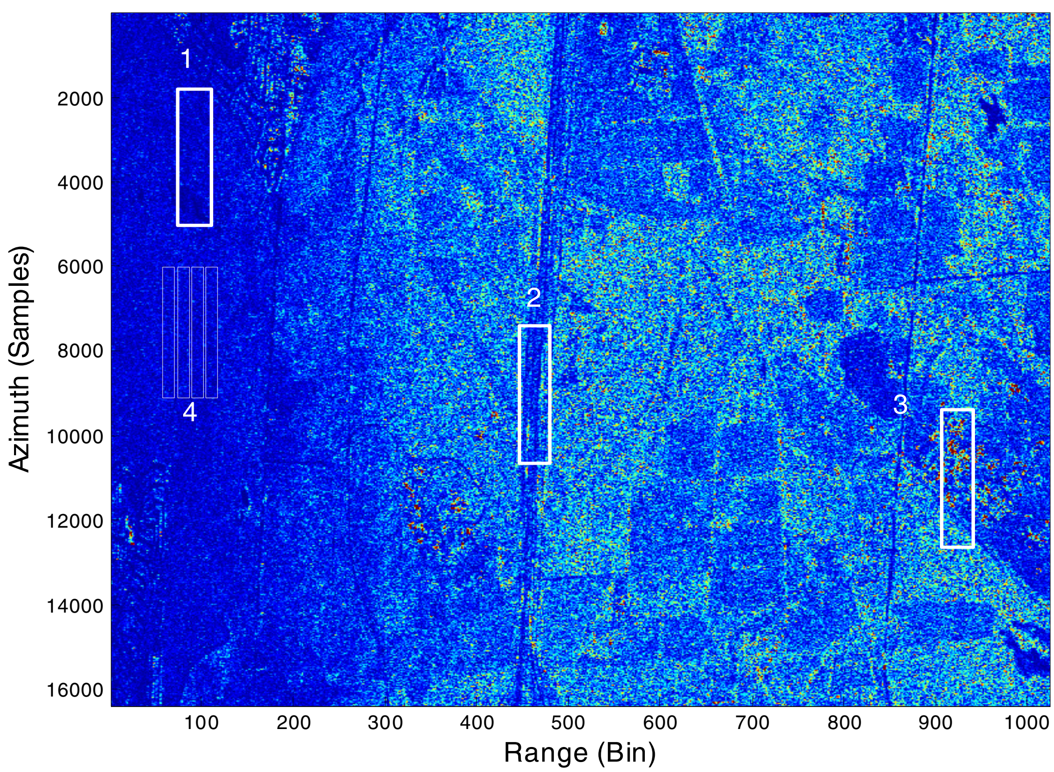


Figure 1. SAR image of Petawawa acquired by Environment Canada`s CV580 C-Band SAR configured in its ATI mode, on November 2000 with indicated 4 different areas used in the simulations.

Simulated targets are embedded in radar clutter signals taken from these different regions. Region 1 is a homogeneous shrubby vegetated area, region 2 is part of a highway, region 3 is part of an urban area, and regions 4 are homogeneous shrubby vegetated areas in close proximity.

2.3 Clutter effects on the ATI phase with respect to varying SCR

In this case, the Signal to Clutter Ratio (SCR) was varied from –10dB to 25dB (SCR values are measured after azimuth compression) to investigate the clutter interaction effects on ATI phase as the target signal varies from the clutter-dominated case to the target-dominated case. Several ATI phase patterns were observed while increasing the SCR in each region.

For region one (a homogenous shrubby vegetated area), the clutter-contaminated interferometric phase of the simulated targets with varying SCR is shown in Fig.2. The interferogramm was calculated as the product of the fore image and the conjugate of the aft image, where the phase of this product is plotted in Figures 2 to 4.

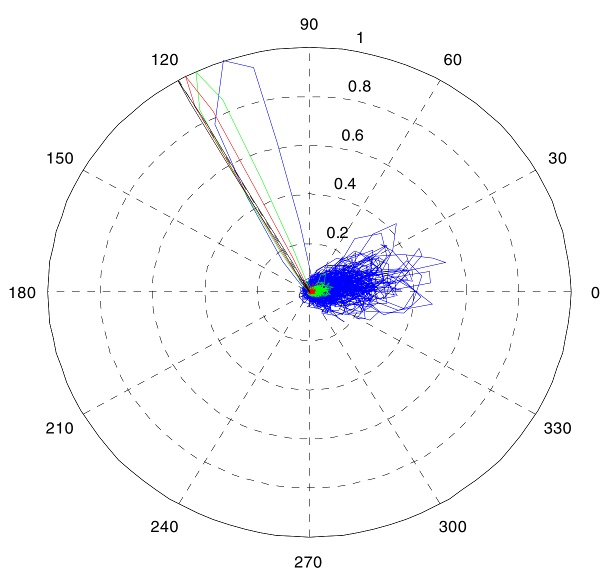


Figure 2. Polar plots of the simulated target's interferograms with different SCRs of region-1. Blue, green, red and black colors represent 0 dB, 7 dB, 14 dB and 25 dB SCRs respectively. The lines connecting the points in all the figures are for visual clarity

For region two (part of a highway), the clutter-contaminated interferometric phase of the simulated targets with varying SCR is shown in Fig. 3.

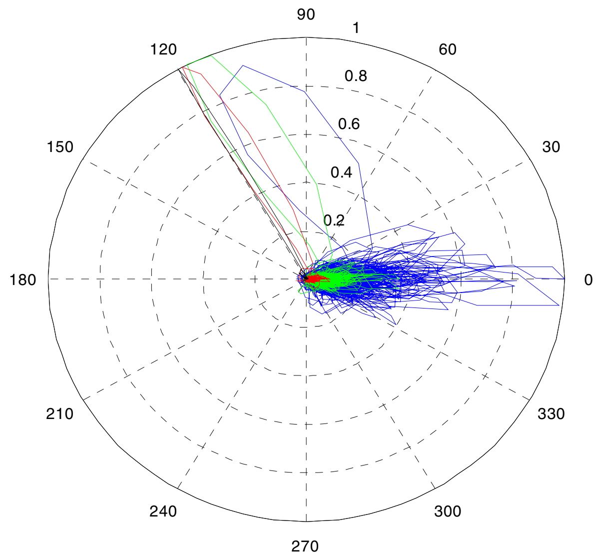


Figure 3. Polar plots of the simulated target's interferograms with different SCRs of region-2. Blue, green, red and black colors represent 3 dB, 8 dB, 14 dB and 25 dB SCRs respectively.

For region 3 (part of an urban area), the clutter contaminated interferograms of the simulated target with varying SCR is shown in Fig.4.

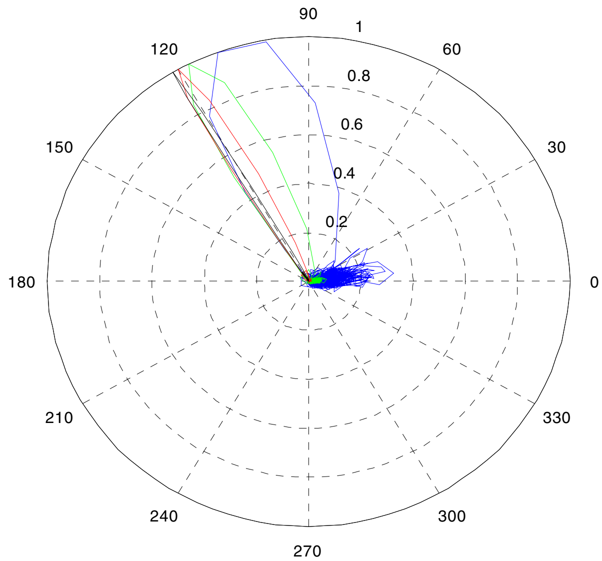


Figure 4. Polar plots of the simulated target's interferograms with different SCRs of region-3. Blue, green, red and black colors represent 0 dB, 7 dB, 14 dB and 25 dB SCRs respectively.

Results show that clutter interference affects the ATI phase estimates even up to 15 dB SCR levels but has little effect when the SCR is above 15 dB. When we compare the ATI phase simulations using three different regions, we can say that we have smaller variance and thus better ATI phase estimates in Region 1 (homogenous shrubby vegetated area) than the other regions, as expected. Also note that even though target magnitude may be detected at relatively low SCRs, the ATI phase shows the serious bias even at a SCR as high as 10 dB, as shown in Fig 5.

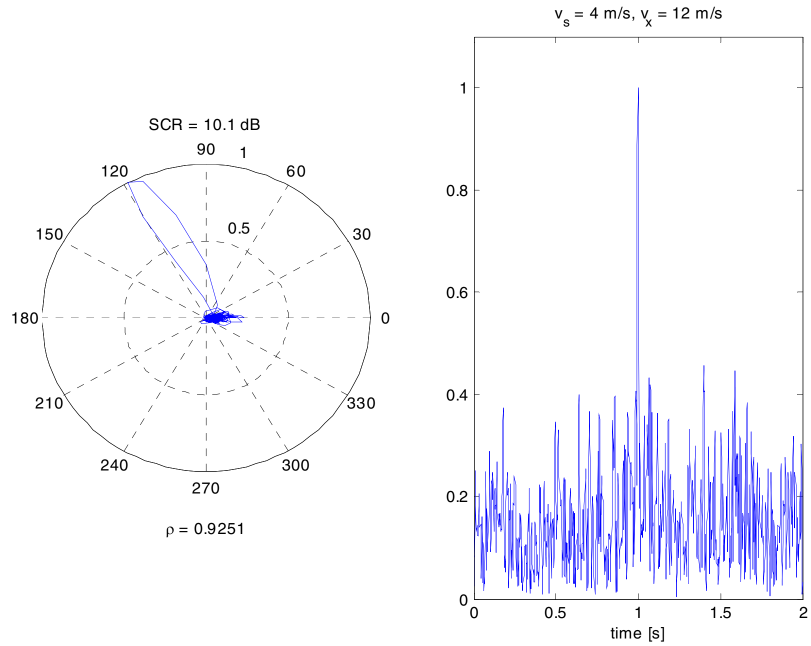


Figure 5. Along-track interferometric phase of the target versus target signal normalized magnitude response at SCR = 10.01 dB.

2.4 Interferograms of different realizations at adjacent clutter areas

In this case, four different realizations are computed using four adjacent clutter areas taken from region 4 shown in Fig. 1. Although the same target parameters are used with the same SCR (7.4 dB) in each simulation, different ATI phase patterns are observed for each selected region as shown in Fig. 6. This indicates not only that the clutter power affects ATI phase estimation but also that a slight variance in supposedly very similar clutter distributions can have a significant effect on ATI phase measurements. This ATI phase behavior is also verified using simulated Gaussian clutter of the same power but with different random generator seeds in section 3.2.

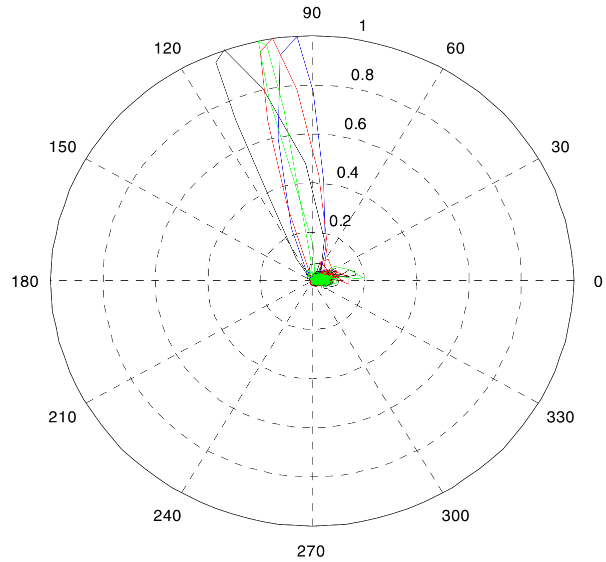


Figure 6. The same target in different but adjacent clutter areas (SCR = 7.4 dB). The SCR is calculated after azimuth compression and the matched filter is matched to the target motion. The lines connecting the points are for visual clarity.

3. Effects of simulated clutter on simulated targets

The quadrature components of a radar channel are often modeled as zero-mean Gaussian processes, which implies a Rayleigh distributed amplitude. The model is warranted for rough (on the scale of the wavelength) homogeneous backscatter amplitude terrain because the sum of independent (rough), identically (homogenous) distributed scatterer, will be complex Gaussian distributed by the Central Limit Theorem. In a typical SAR image, the model results in granularity commonly denoted as speckle. The model has been validated over homogeneous agricultural and natural areas, but breaks down over more heterogeneous or smooth surfaces such as urban or sea surfaces [11].

In this report, Gaussian (homogeneous) clutter is used as the simulated clutter of a homogenous area. The detailed clutter models (homogenous and heterogeneous) have been described in [3] and [11].

3.1 Simulated target with one realization of simulated homogenous clutter

In this test case, homogenous (Gaussian) simulated clutter was used to look at the effect of clutter realization on the detection and estimation problems at constant target parameters. This work examines the limitations of using a single section of a single scene as a basis for judging target-to-clutter effects. The ATI phase angles and magnitudes of the simulated target signal in simulated clutter with increasing SCRs are shown in Figs. 7(a)-7(d).

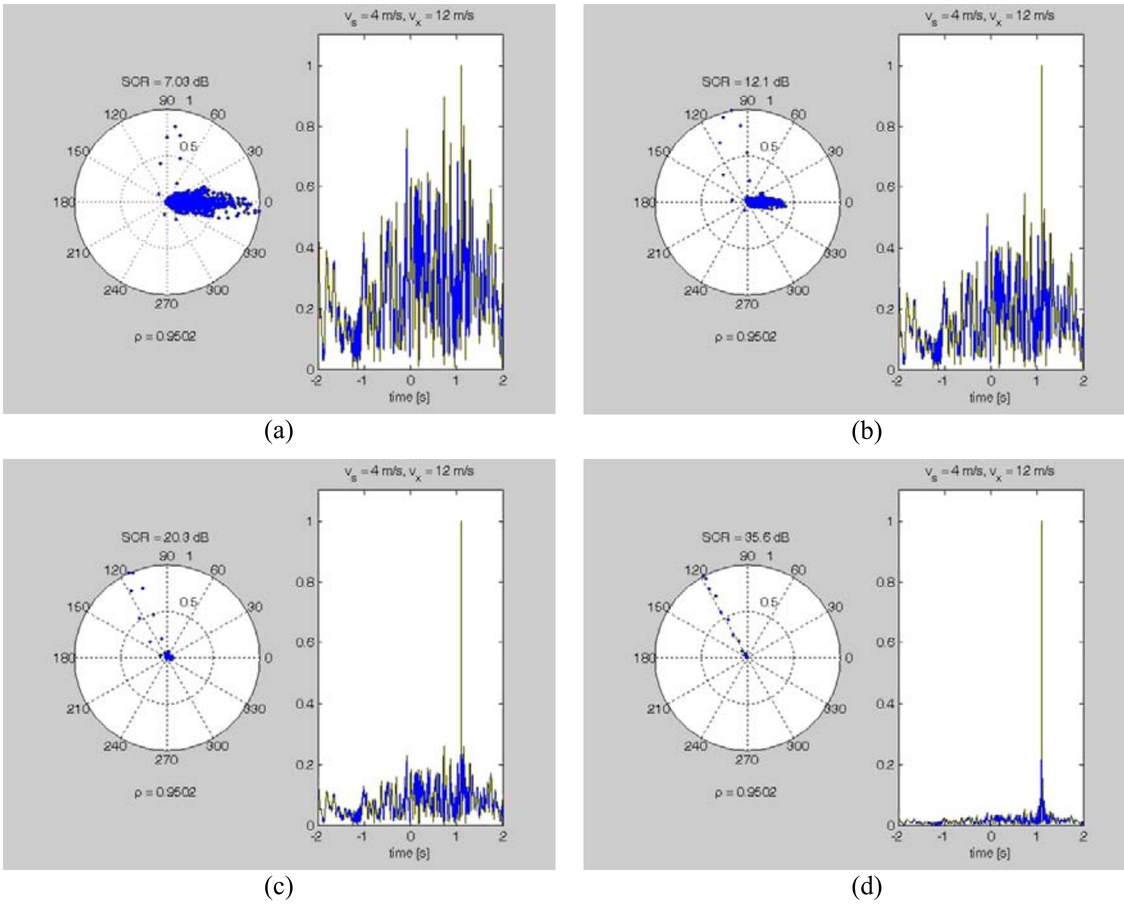


Figure 7. (a) - (d) The ATI phase angles and magnitudes of the simulated target signal in simulated homogenous (Gaussian) clutter with 7.03dB, 12.1dB, 20.3dB and 35.6dB SCRs respectively.

3.2 Simulated target with several different clutter realizations of homogenous terrain

In this test case, homogenous (Gaussian) simulated clutter was used to look at the effect of clutter realization on the detection and estimation problems at constant target parameters. Although the same normally distributed random process was simulated as homogenous simulated clutter, very diverse ATI phase patterns were observed at each trial as shown in Fig.8. At the end of the simulations with constant SCR trials, it was confirmed that we could see almost 15 degrees of variation in measured ATI phase angles at 20dB SCR. That means, not only the clutter power but also the clutter distribution affects the estimation of ATI phase of the intended target signal. The ATI phase angles of the simulated target signal with several different clutter realizations are shown in Fig. 8.

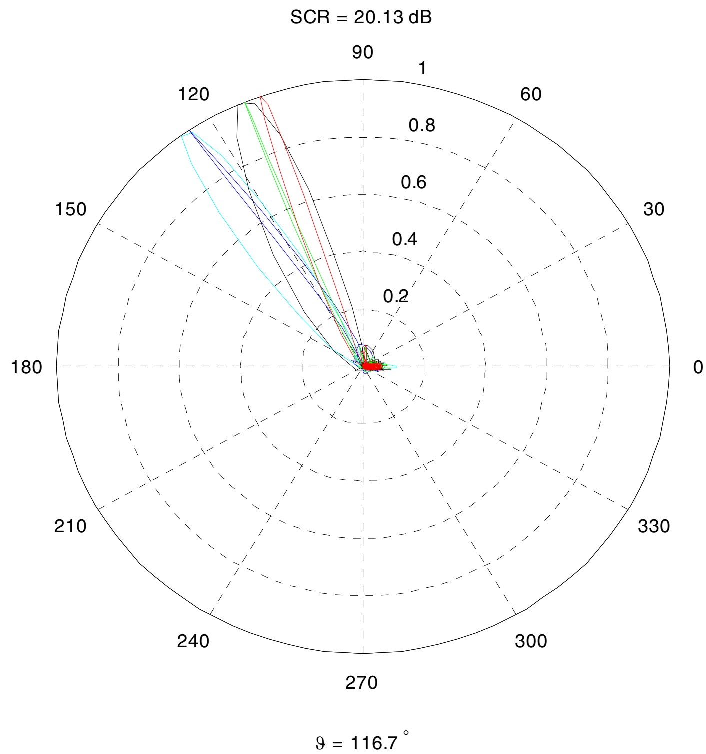


Figure 8. Polar plots of the simulated target's interferograms with several different homogenous clutter realizations at 20.13 dB of SCR. The lines connecting the points are for visual clarity.

3.3 Simulated target and homogenous clutter with four clutter spikes

In this test case, four clutter spikes which have much higher magnitudes than the average noise level (one exactly at t_c , the time of the closest approach between the radar and the target, and –10 dB smaller than the target) were added into homogenous simulated clutter. Being different from the previous simulations, the SCR was kept constant to show the enormous effects of the instantaneous clutter spikes. At the end of the simulations with constant SCR trials, it was confirmed that we could see almost 50 degrees of bias in ATI phase angles at 15 dB SCR and more than 30 degrees of bias in ATI phase angles at 20dB SCR. The ATI phase angles of the simulated target with homogenous clutter and four clutter spikes at constant SCR were shown as polar plots in Figs. 9(a)-9(b).

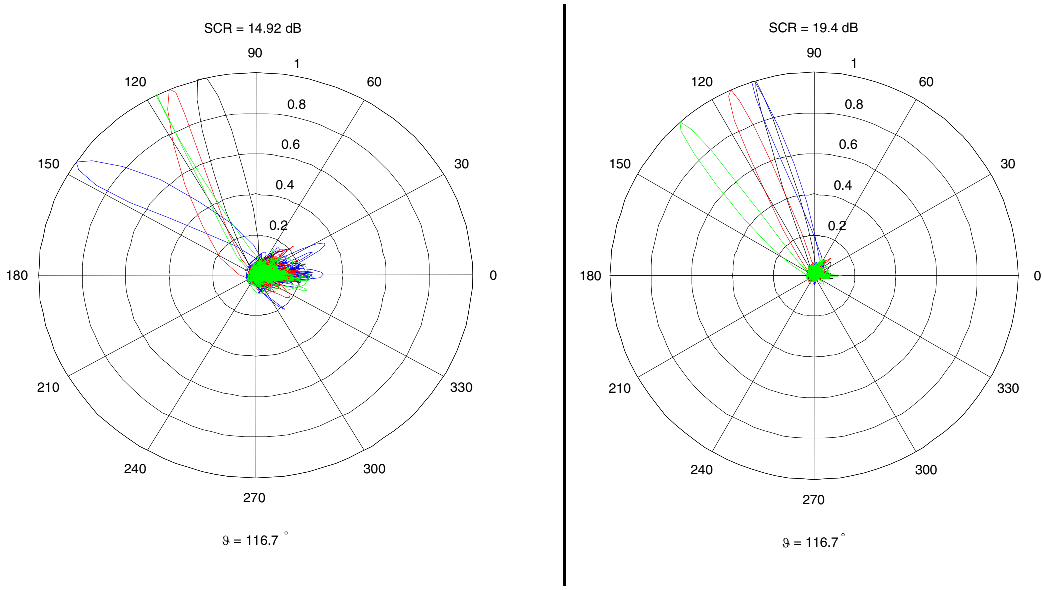


Figure 9. (a) – (b) The ATI phase angles of the simulated target with homogenous clutter and four clutter spikes at 15dB and 20dB of SCRs respectively. The lines connecting the points are for visual clarity.

4. Variation of target radar cross section (RCS) over time

In the previous sections, simulations were carried out using deterministic point targets with constant magnitude (unity). In real life, the radar cross-section (RCS) of a target depends on the three factors, geometric cross section, reflectivity and directivity. Therefore, a radar receiver may receive targets' echoes with varying magnitudes over time.

In this section the variation of target RCS was examined. Figure 10(a) shows the constant target magnitude used in the previous simulations. Adding an uniformly distributed signal to the original target we have the new target signal magnitude shown in figure 10(b).

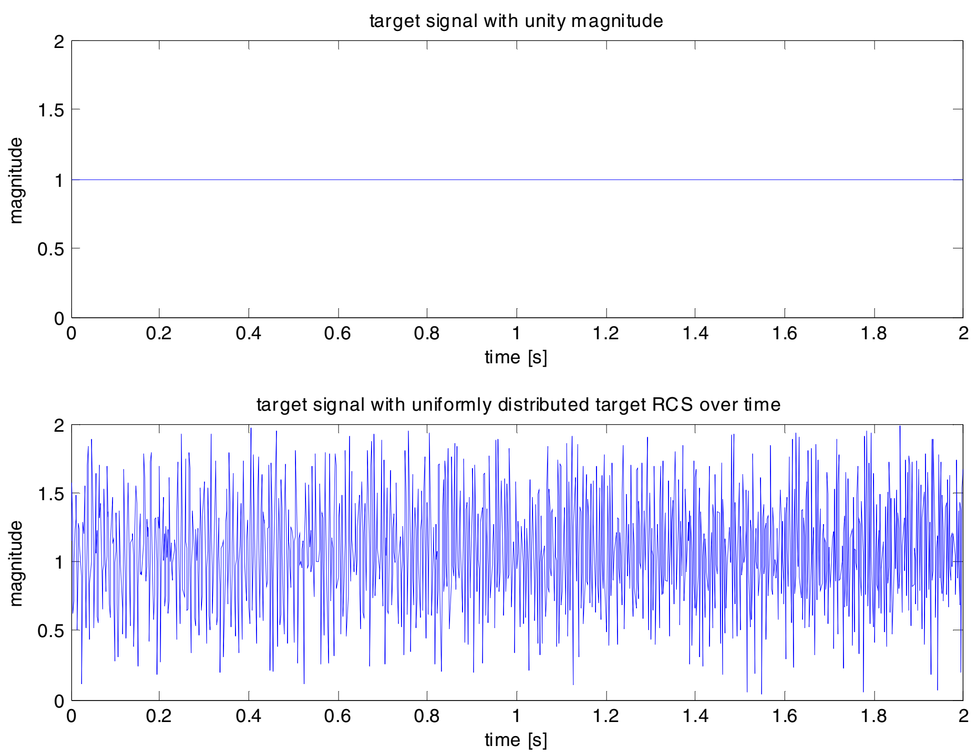


Figure 10. (a) Target signal with constant magnitude. (b) Target signal magnitude including uniformly distributed RCS over time.

The ATI phase angle of the simulated target signal with constant unity magnitude (Fig.10(a)) and the ATI phase angle of the simulated target signal with uniformly distributed varying magnitudes (Fig.10(b)) are shown in red and blue colours respectively in figure 11. In the simulations, reasonable SCR (12.4 dB) was used to see the effects of the varying target magnitudes which represent the varying target RCS over time. As we see from figure 11, results show that there is no significant bias in the ATI phases of the two simulated target signals. We can say that varying RCSs of the moving target over time do not have any significant effect on the ATI phase. We can conclude that target magnitude variations do not have any effect on the ATI phase as long as there are no extended gaps in the reflectivity.

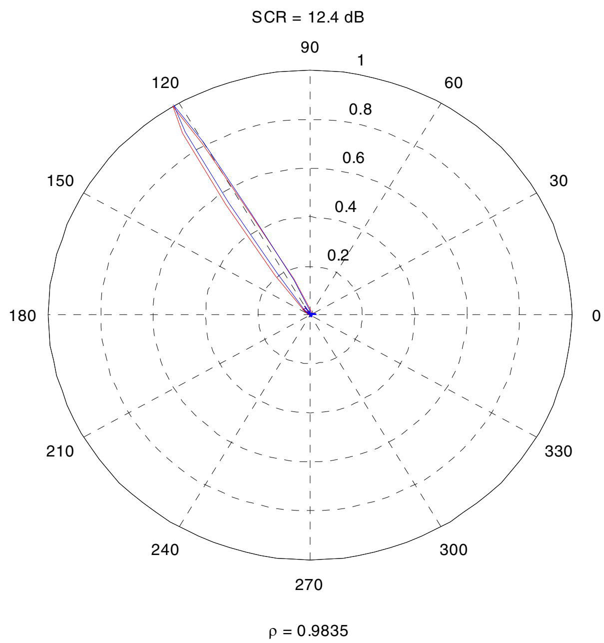


Figure 11. The ATI phases of the target signal with constant magnitude (red colour) and target signal with normally distributed varying magnitudes over time (blue colour). The lines connecting the points are for visual clarity.

5. The effects of the target acceleration on the ATI phase

In the previous sections, like the most of the GMTI literature, we assumed that targets traveled with constant velocity. In this section, the effects of target acceleration on the ATI phase including both along-track acceleration and across-track acceleration are examined through simulations because one potential application of GMTI is monitoring vehicle traffic on roads and highways where target acceleration is a commonplace.

5.1 Slant range equation for the accelerating target

The range equation for an accelerating target from the radar platform at any time is given as

$$R(t) = \left(\left(v_{x0}t + \frac{a_{x0}}{2}t^2 + \frac{\dot{a}_x(0)}{6}t^3 - v_a t\right)^2 + \left(y_0 + v_{y0}t + \frac{a_{y0}}{2}t^2 + \frac{\dot{a}_y(0)}{6}t^3\right)^2 + H^2\right)^{\frac{1}{2}} \quad (4)$$

where a_{x0} and a_{y0} are the across-track and along-track accelerations at broadside, and the dots indicate time derivatives of the target acceleration (higher order terms are assumed to be negligible). Equation (4) may be written as a third order Taylor series expansion about broadside time $t=0$;

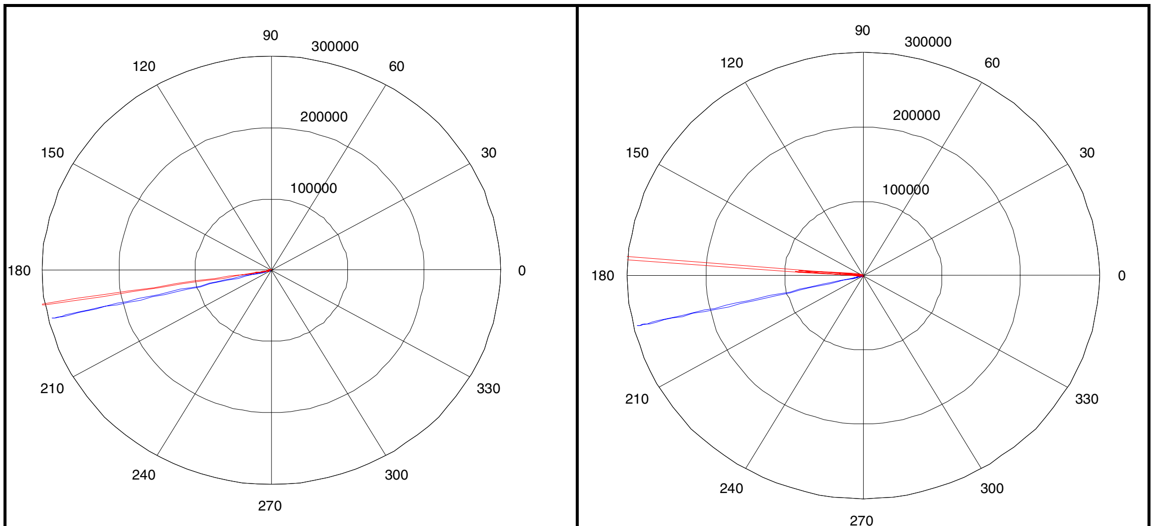
$$R(t) \approx R_0 + \frac{y_0 v_{y0}}{R_0}t + \frac{1}{2R_0}\left[(v_{x0} - v_a)^2 + v_{y0}^2\left(1 - \frac{y_0^2}{R_0^2}\right) + y_0 a_{y0}\right]t^2$$

$$+ \frac{1}{2R_0}\left[v_{y0}a_{y0}\left(1 - \frac{y_0^2}{R_0^2}\right) + a_{x0}(v_{x0} - v_a) + \frac{y_0 \dot{a}_y(0)}{3}\right]t^3 \quad (5)$$

where cubic terms on the order of $1/R_0^2$ have been dropped [12]. In this section the effects of acceleration component a_{y0} is examined.

5.2 Variation in ATI with a_{y0}

Because a_{y0} is multiplied by y_0 in eq.(5), we can expect that even small accelerations will have a significant impact upon the ATI phase. For example, for v_{x0} = 0 m/s and v_{y0} = 10 m/s, when we change a_{y0} from 0 m/s^2 to 0.1 m/s^2, the ATI phase shifts almost 4 degrees. At the same conditions, when we increase a_{y0} to 0.5 m/s^2, the ATI phase shifts almost 15 degrees. Simulations showing the effect of a_{y0} on ATI phase are shown in Figure 12.



(a) a_{y0} = 0.1 m/s^2 (red line)

(b) a_{y0} = 0.5 m/s^2 (red line)

Figure 12. The ATI phase shifts according to the changes in a_{y0}. Blue lines show the ATI phases when a_{y0} = 0. The lines connecting the points are for visual clarity.

From the simulations shown above, we can conclude that neglecting the contributions of a_{y0} to the ATI phase can give erroneous estimates.

5.3 Variation in ATI with a_{x0}

Compared to a_{y0}, a_{x0} has a relatively small impact on ATI phase. For a_{x0} varied from −1 to 1 m/s^2 (scanned in steps of 0.1 m/s), the maximum deviation was found to be 2.4 degrees. Thus, for the parameter ranges examined, the effects of a_{x0} on ATI phase are nearly an order of magnitude lower than the influence of a_{y0} [12].

6. Conclusions

The clutter effects on the along-track interferometric phase of simulated moving targets using different simulation scenarios and the reasons of the biases in the measured ATI phase angles of the moving targets were investigated.

The analysis of clutter interference on two-channel SAR along-track interferograms has demonstrated the uncertainty of ATI phase even for relatively low levels of clutter contamination. Simulations with real clutter show that not only the clutter power affects ATI phase estimation but also a slight variance in supposedly very similar clutter distributions can have a significant effect on ATI phase measurements. Simulations using simulated clutter show that both the clutter power and the clutter distribution significantly affect the estimation of ATI phase of the intended target signal.

We can say that varying RCSs of the moving target over time do not have any significant effect on the ATI phase. That shows us that target magnitude variations do not have any effect on the ATI phase as long as there are no extended gaps in the reflectivity.

As a last comment, the target acceleration on the across-track direction has a significant effect on the ATI phase. We can conclude that neglecting the contributions of a_{y0} to the ATI phase can give erroneous estimates.

7. References

1. Chiu, S., Livingstone, C., Knight, T. and Sikaneta, I. (2000). Computer Simulations of Canada's RADARSAT2 GMTI. In Space based observation technology hosted by NATO panel: Sensors & Electronics, Greece.

2. Gierull, C.H. and Livingstone, C. (2003). SAR-GMTI concept for RADARSAT-2 *in The Applications of Space-Time Processing* (R.Klemm, ed.), Stevenage, UK: IEE Press.

3. Gierull, C.H. (2002). Statistics of SAR Interferograms with Application to Moving Target Detection. (DRDC Ottawa TR 2001-045). Defence R&D Canada - Ottawa.

4. Raney, R.K. (1971). Synthetic aperture imaging radar and moving targets. IEEE Transactions on Aerospace and Electronic Systems, AES-7(3), pp. 499-505.

5. Chiu, S. Gierull, C.H., Durak, A. (2005). Clutter effects on ground moving targets' interferometric phase. In IGARSS'05, S. Korea, 25-29.

6. Chiu, S. (2003). Clutter effects on ground moving target velocity estimation with SAR along-track interferometry. In IGARSS'03, Toulouse, France, 21-25.

7. Gierull, C.H. (2002) Moving target detection with along-track SAR interferometry. (DRDC Ottawa TR 2002-084). Defence R&D Canada-Ottawa.

8. Chiu, S. (2001). Two-channel SAR-GMTI via Fractional Fourier Transform. (DRDC Ottawa TM 2001-172). Defence R&D Canada-Ottawa.

9. Gierull, C.H., Sikaneta, I. (2004). Ground Moving Target Parameter Estimation for two-Channel SAR. IEEE Aerospace Conference.

10. Livingstone, C.E., Sikaneta, I., Gierull, C.H., Chiu, S., Beaudoin, A., Campbell, J., Beaudoin, J., Gong, S., Knight, T.A. (2002). An airborne SAR experiment to support RADARSAT-2 GMTI. Can. J. Remote Sensing, Vol. 28, No. 6, pp. 794-813.

11. Gierull, C.H. (2002). Statistics of Multilook SAR Interferograms for CFAR Detection of Ground Moving Targets. EUSAR2002.

12. Sharma, J.J., C.H., Collins, M.J. (2004). Simulation of SAR Signals From Moving Vehicles (Focusing Accelerating Ground Moving Targets). EUSAR.

List of symbols/abbreviations/acronyms/initialisms

DND	Department of National Defence
GMTI	Ground Moving Target Indication
MODEX	Moving Object Detection Experiment
ATI	Along-Track Interferometry
SCR	Signal-to-Clutter Ratio
SAR	Synthetic Aperture Radar
RCS	Radar Cross Section
PRF	Pulse Repetition Frequency

Glossary

Technical term	Explanation of term
a_{x0}	target along-track acceleration at broadside time t = 0
a_{y0}	target across-track acceleration at broadside time t = 0
x_0	azimuth location at time $t=0$
y_0	range location at time $t=0$
v_x	along-track velocity of the target
v_y	across-track velocity of the target
v_a	velocity of radar platform
H	altitude of radar platform
ν_r	slant range velocity
τ	time between two observations
λ	wavelength
d	physical antenna separation distance
R_0	range to target at broadside time t = 0
R(t)	range to the target as a function of time
t_c	time of the closest approach between the radar and the target

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(U) This report mainly investigates the clutter contamination problem for a two-channel radar system using both simulated and realistic clutter (measured airborne data). The objective of this study is to show the clutter effects on the interferometric phase of simulated moving targets using different simulation scenarios and to investigate the reasons for the biases in the measured ATI phase angles of the moving targets. Simulations show that not only the clutter power affects ATI phase estimation but also a slight variance in supposedly very similar clutter distributions can have a significant effect on ATI phase measurements.

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ALONG-TRACK INTERFEROMETRY
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STATISTICS OF SAR INTERFEROGRAMS

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