RLSTAP Trials
Under BISTAP Call-up 2

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EXECUTIVE SUMMARY

DRDC (Defense R&D Canada) Ottawa is generating bistatic radar scenarios using the RLSTAP (Research Laboratory Space-Time Adaptive Processing) Simulation Tool, developed by CAE Soft Corp. and Raytheon Systems Company, for the purposes of investigating bistatic data signal processing. This report is meant to track the testing performed by Vantage Point International Inc. under call-up 2 of the Bistap project (DRDC-O standing offer W7714-1-0566). The focus of this testing was to verify RLSTAP operation under various scenarios, resolve any problems discovered when generating these scenarios, and verify bistatic range and Doppler placement of clutter and target returns.

Scenarios were initially developed using homogeneous clutter types and a transmitter platform with an altitude of 100 km. Three types of scenarios were developed so that the receiver and transmitter velocity vectors were perpendicular, parallel, and intersecting at 45 degrees. During testing, it was discovered that higher altitude platforms were possible by setting the RLSTAP maximum and minimum simulation space and burn pulses appropriately. Scenarios were then modified to implement a MEO (Medium Earth Orbit) transmitter and later to support site-specific clutter types such as the Ottawa, Ontario and Roswell, New Mexico areas.

Due to the large memory requirements of the site-specific clutter scatterer fields at 3 arc-second resolution, the fields were either reduced to 9 arc-second resolution or broken into tiles, which could be generated individually. The datacubes from the individual tiles could be summed and processed as if the whole scatterer field was generated.

Once RLSTAP lineups have been prepared it is desirable to run them from the command line using a batch script. This was not initially possible due to a number of glyphs that continue to run even after the desired number of PRIs has been processed. A workaround was developed which allowed batch processing using a combination of the sleep and kill UNIX commands on multiple simultaneous command lines.

The initial series of datacubes generated using RLSTAP were processed using two-dimensional Angle-Doppler Fast Fourier Transform and Joint Domain Localized Space-Time Adaptive Processing (JDL-STAP) MATLAB routines supplied by the scientific authority at DRDC-O. These routines were used to qualify target detection under various scenarios. For the later series, other MATLAB scripts were developed to verify the bistatic range and Doppler of the clutter and target results.

A number of tips and cautions were noted during testing. Some of these are described in the RLSTAP documentation. Additional tips and cautions are provided in this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 Introduction

1.1 Background

DRDC (Defense R&D Canada) Ottawa is generating bistatic radar scenarios using the RLSTAP (Research Laboratory Space-Time Adaptive Processing) Simulation Tool, developed by CAE Soft Corp. and Raytheon Systems Company, for the purposes of investigating bistatic data signal processing. This report is meant to track the testing performed by Vantage Point International Inc. under call-up 2 of the Bistap project.   The focus of this testing was to verify RLSTAP operation under various scenarios, resolve any problems discovered when generating these scenarios, and verify bistatic range and Doppler placement of clutter and target returns. Some of the initial results were also processed using two-dimensional Angle-Doppler Fast Fourier Transform (2DFFT) and Joint Domain Localized Space-Time Adaptive Processing (JDL-STAP) MATLAB routines provided by the DRDC scientific authority.

1.2 Document and Software Scope

This document assumes that the reader has good knowledge of the RLSTAP simulation tool and how it is used. The reader should also have a background in bistatic radar and the signal processing techniques associated with bistatic data such 2DFFTs and JDL-STAP.

The RLSTAP scenarios that were requested, the testing methods, and the results from February 18th though November 5th series are detailed. All problems encountered and the solutions (if found) are included. Only the February 18th series was processed using 2DFFTs and JDL-STAP. A detailed description of either 2DFFTs or JDL-STAP is not within the scope of this document. Processing of the other series was limited to verification of bistatic range and Doppler placement of clutter and targets.

This document does not contain a description of the KHOROS software (Khoral Inc.) upon which RLSTAP is built or a description of RLSTAP and its usage. It is suggested that the user read the RLSTAP v3.18D User's manual (Callaham & McKay, 2003) and that the RLSTAP Interface Control Documents (ICD) (McKay, 2003) be consulted for detailed descriptions of glyph usage.

2 RLSTAP Scenarios

RLSTAP scenarios were developed using the CANTATA program (GUI based workspace/scenario editor and execution tool). Each scenario was saved as an individual lineup (*.wk) file. The organization of glyphs within the lineups is shown in Appendix C (Lineup Glyph Organization). The range-pulse-channel datacubes that are output after the lineups were executed are saved as individual MATLAB (*.mat) files. RLSTAP scenarios were initially developed using low altitude transmitter, receiver, and target platforms and homogeneous clutter types. Three types of scenarios were developed so that the receiver and transmitter velocity vectors were perpendicular, parallel, and intersecting at 45 degrees. During testing, it was discovered that higher altitude platforms were possible by setting the RLSTAP maximum and minimum simulation space and burn pulses appropriately. Scenarios (June 19th and later) were modified to implement a MEO (Medium Earth Orbit) transmitter. Support for site-specific clutter types such as the Ottawa, Ontario and Roswell, New Mexico areas was also added during testing.

Each of the following sections include a table listing the parameters modified for each series.   The parameters are given a general name associated with their usage. Appendix A (Toolbox, Glyph, and Parameter Names) provides a table listing the toolbox, glyph name, and glyph parameter names for each of these general parameters. The lineups also contain several parameters that are not modified from series to series. These parameters and their settings are listed in Appendix B (Scenario Independent Lineup Parameters).

2.1 February 18 Series

2.1.1 Purpose

The series of scenarios requested on February 18, 2003 were first prepared for RLSTAP 3.13. These scenarios were designed using a low altitude transmitter, receiver, and target. The scenarios are broken into three types by the intersection angle between the transmitter and receiver velocity vectors (90, 45, and 0 degrees). Figure 1 shows relative positions of the transmitter, receiver, and target platforms for the three scenarios. The platforms are given south and east offsets from the platform trajectory reference location (PTRL), which is centered at a specific latitude and longitude. Three datacubes were generated for each scenario using homogeneous agricultural clutter, a 10 dB RCS target, and a −10 dB RCS target independently. When RLSTAP was upgraded from version 3.13 to 3.18D the scenario lineups were modified due to the loss and replacement of glyphs. Consult the RLSTAP v3.18D upgrade presentation (Callaham, 2003b) for a detailed description of the changes made to RLSTAP. The results of these scenarios were used to qualify target detection using 2DFFTs and JDL-STAP.
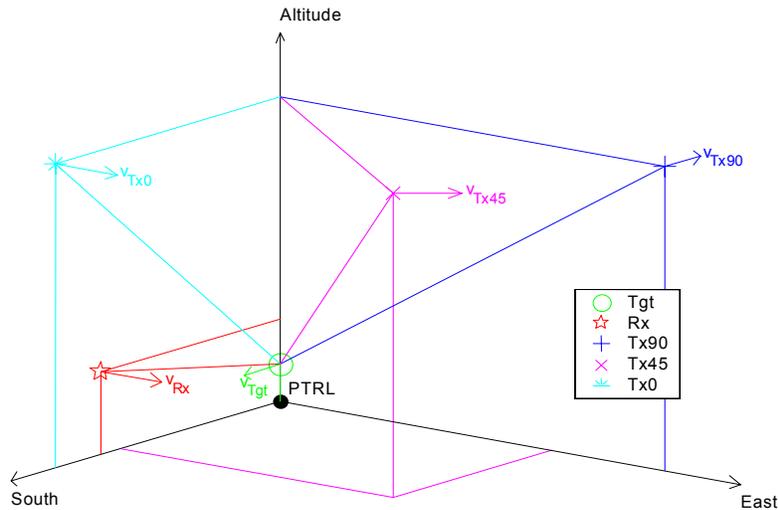
Figure 1: Relative Platform Positions

2.1.2 Lineup Parameters

Table 1 lists the main parameters used for the February 18th lineups. The table is separated into sections based on general simulation parameters (SIM), transmitter antenna (TX ANT) and platform parameters (TXPLAT), receiver antenna (RX ANT) and platform parameters (RX PLAT), target parameters (TGT), and clutter scatterer parameters (CLUT). The value column is separated into 90, 45, and 0 columns when the corresponding parameter changes for those scenarios.

Table 1: Feb 18 Series Lineup Parameters

Parameter			Value by Scenario			Units
			90	45	0	
SIM		CPIs		1		
		Pulses		32 + 12 burn pulses		
		Sampling Rate		10E6		Hz
		Min Range Extent		1E3		m
		Max Range Extent		550E3		m
TX	**ANT**	H Array Points		300		
		H Points Spacing		0.1		m
		V Array Points		300		
		V Points Spacing		0.1		m
		Freq		1.5E9		Hz

		Parameter				Units
		Mech. AZ	-90			° (+CW from Yaw)
		Mech. EL	-11.25			° (-ve down from Pitch)
		Peak Power	100E3			W
		PRI	250E-6			s
		PW	26E-6			s
		Burn Pulses	12			
	PLAT	Altitude	100E3			m
		LAT	0			°
		LONG	0			°
		East Offset	500E3	353553.4	0	m
		North Offset	20E3	-333553.4	-480E3	m
		Velocity East	0	3889.1	5500	m/s
		Velocity North	5500	3889.1	0	m/s
		Yaw (Heading)	0	45	90	° (+ve CW from north)
RX	ANT	H Array Points	50			
		H Points Spacing	0.1			m
		V Array Points	5			
		V Points Spacing	0.1			m
		Freq	1.5E9			Hz
		Mech. AZ	-90			° (+CW from Yaw)
		Mech. EL	-4.29			° (-ve down from Pitch)
		Noise	3			dB
	PLAT	Altitude	2E3			m
		LAT	0			°
		LONG	0			°
		East Offset	0			m
		North Offset	0			m
		Velocity East	280			m/s
		Velocity North	0			m/s
		Yaw (Heading)	90			° (+ve CW from north)
TGT		Altitude	500			m
		LAT	0			°
		LONG	0			°
		East Offset	0			m
		North Offset	20E3			m
		RCS	0.1 & 10			m^2
		Velocity East	0			m/s
		Velocity North	-100			m/s

	Yaw (Heading)	180	º (+CW from North)
CLUT	LAT Increment	0.001	º
	LAT NE Corner	0.2	º
	LAT SW Corner	-0.2	º
	LONG Increment	0.001	º
	LONG NE Corner	0.3	º
	LONG SW Corner	-0.3	º
	Resolution	3.6	Arc-seconds
	Type	Homogeneous Agricultural	

Table 2 lists the filenames used for the lineup files (*.wk) and the resulting datacube files (*.mat). For this series the clutter lineups included receiver noise. Ten Monte Carlo runs were generated for the clutter lineups and the resulting datacubes have a letter (a through j) appended to the filename representing the run. Target lineups were generated for both 10 m^2 (10 dBsm) and 0.1 m^2 (-10 dBsm) radar cross section (RCS) targets. RLSTAP was upgraded from version 3.13 to 3.18D during testing so new lineups were generated due to the removal and replacement of glyphs. Comparison of the resulting datacubes showed that the upgrade did not affect the signal return generated by RLSTAP. The target section of the table is divided according RCS values 0.1 and 10 m^2.

Table 2: Feb 18 Series Lineup (*.wk) and Datacube (*.mat) Filenames

		90	45	0
Homogeneous Agricultural Clutter		int_noise_lineup_001. wk (RLSTAP 3.13) int_noise_lineup_004. wk (RLSTAP 3.18D)	int_noise_lineup_002. wk (RLSTAP 3.13) int_noise_lineup_005. wk (RLSTAP 3.18D)	int_noise_lineup_003. wk (RLSTAP 3.13) int_noise_lineup_006. wk (RLSTAP 3.18D)
		iline001a-j.mat	iline002a-j.mat	iline003a-j.mat
Target	**0.1 m^2**	tgt_lineup_001.wk (RLSTAP 3.13) tgt_lineup_007.wk (RLSTAP 3.18D)	tgt_lineup_002.wk (RLSTAP 3.13) tgt_lineup_008.wk (RLSTAP 3.18D)	tgt_lineup_003.wk (RLSTAP 3.13) tgt_lineup_009.wk (RLSTAP 3.18D)
		tline001.mat	tline002.mat	tline003.mat
	10 m^2	tgt_lineup_004.wk (RLSTAP 3.13) tgt_lineup_010.wk (RLSTAP 3.18D)	tgt_lineup_005.wk (RLSTAP 3.13) tgt_lineup_011.wk (RLSTAP 3.18D)	tgt_lineup_006.wk(RLSTAP 3.13) tgt_lineup_012.wk (RLSTAP 3.18D)
		tline004.mat	tline005.mat	tline006.mat

2.1.3 Simulation Notes

Transmitter altitude was initially limited based on an assumed RLSTAP limitation. Testing has shown that there is an indirect limitation on transmitter altitude based on the limited number of simulation space samples (256K samples) that can be handled by RLSTAP. The maximum range, minimum range, and simulation sampling frequency parameters, found in the simulation controller (SIMCON) glyph, must be set so that the maximum number of simulation space samples is not exceeded. These parameters are discussed in detail in section 3.1.

2.2 June 19 Series

2.2.1 Purpose

The June 19th series was designed to position a transmitter at a medium earth orbit (MEO). In these scenarios, both the target and the transmitter were positioned directly at the PTRL but at different altitudes. The transmitter antenna was pointed straight down on the target. For the 90, 45, and 0-degree scenarios, the receiver was moved so that its velocity vector was perpendicular, at 45 degrees, and parallel to the transmitter velocity vector. The target velocity vector was also adjusted for each scenario so that it was always perpendicular to the receiver velocity vector. The relative platform positions are shown in figure 2. The Ottawa site-specific scatterer field was also tested in this series.
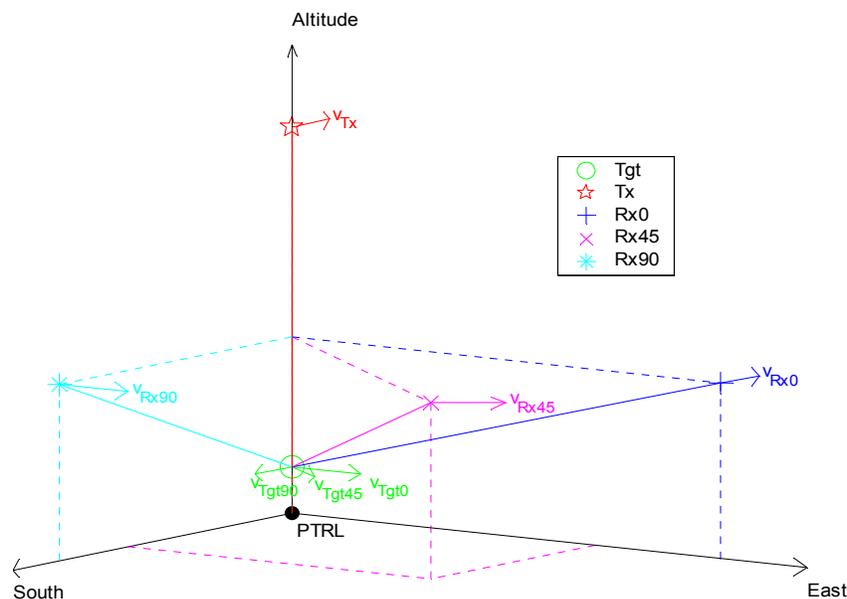
Figure 2: Modified Relative Platform Positions

2.2.2 Lineup Parameters

Table 3 lists the main parameters used for the June 19th lineups. The table is separated into sections based on general simulation parameters (SIM), transmitter antenna (TX ANT) and platform parameters (TXPLAT), receiver antenna (RX ANT) and platform parameters (RX PLAT), target parameters (TGT), and clutter scatterer parameters (CLUT). In applicable cases, the parameter value column is split according to scenario (90, 45, and 0). For this series a site-specific scatterer field centered on 45.5° latitude, -75° longitude (near Ottawa, ON) was also used. Because the LULC (land-use/land-cover) files that RLSTAP requires to generate scatterer fields are only available for US locales, a special process is required to produce scatterer fields for the Ottawa area. This process is described in a DRDC-O report written by Steven Hughes (2002). Due to the large memory requirements of the scatterer field at 3 arc-second resolution, the lineups were modified to reduce the resolution to 9 arc-seconds. A detailed description of this process and how it was tested is provided in section 4.1. Target lineups were again generated for both 10 m^2 and 0.1 m^2 RCS targets.

Table 3: Jun 19 Series Lineup Parameters

		Parameter	Value by Scenario			Units
			90	**45**	**0**	
SIM		CPIs	1			
		Pulses	32 + 87 burn pulses			
		Sampling Rate	10E6			Hz
		Min Range Extent	5.01E6			m
		Max Range Extent	5.11E6			m
TX	**ANT**	H Array Points	200			
		H Points Spacing	0.15			m
		V Array Points	200			
		V Points Spacing	0.15			m
		Freq	1E9			Hz
		Mech. AZ	180			° (+CW from Yaw)
		Mech. EL	-90			° (-ve down from Pitch)
		Peak Power	1.15E6			W
		PRI	390E-6			s
		PW	39E-6			s
		Burn Pulses	87			
	PLAT	Altitude	10E6			m
		LAT	45.5			°
		LONG	-75			°
		East Offset	0			m
		North Offset	0			m
		Velocity East	0			m/s
		Velocity North	4467			m/s

		Yaw (Heading)	0			° (+ve CW from north)
RX	**ANT**	H Array Points	34			
		H Points Spacing	0.15			m
		V Array Points	5			
		V Points Spacing	0.15			m
		Freq	1E9			Hz
		Mech. AZ	-90			° (+CW from Yaw)
		Mech. EL	-9.37			° (-ve down from Pitch)
		Noise	0			dB
	PLAT	Altitude	19.5E3			m
		LAT	45.5			°
		LONG	-75			°
		East Offset	0	70.7	100	m
		North Offset	-100	-70.7	0	m
		Velocity East	176.39	124.73	0	m/s
		Velocity North	0	124.73	176.39	m/s
		Yaw (Heading)	90	45	0	° (+ve CW from north)
TGT		Altitude	3E3			m
		LAT	45.5			°
		LONG	-75			°
		East Offset	0			m
		North Offset	0			m
		RCS	10 & 0.1			m^2
		Velocity East	0	97.86	138.89	m/s
		Velocity North	-138.89	-97.86	0	m/s
		Yaw (Heading)	180	135	90	° (+CW from North)
CLUT		LAT Increment	2.503E-3			°
		LAT NE Corner	46			°
		LAT SW Corner	45			°
		LONG Increment	2.503E-3			°
		LONG NE Corner	-74			°
		LONG SW Corner	-76			°
		Resolution	9			Arc-seconds
		Type	Homogeneous & Ottawa Site-specific			
		Ottawa Material Code Rescale Factor	0.3335			Refer to section 7, item 7

Table 4 lists the filenames used for the lineup files (*.wk) and the resulting datacube files (*.mat). These lineups did not include receiver noise. An independent noise only datacube was generated for processing purposes.

Table 4: Jun 19 Series Lineup (*.wk) and Datacube (*.mat) Filenames

		90	45	0
Homogeneous Agricultural Clutter		int_noise_lineup_010 a.wk	int_noise_lineup_011 a.wk	int_noise_lineup_012 a.wk
		iline010a.mat	iline011a.mat	iline012a.mat
Ottawa Site-Specific Clutter		int_noise_lineup_010 c.wk	int_noise_lineup_011 c.wk	int_noise_lineup_012 c.wk
		iline010c.mat	iline011c.mat	iline012c.mat
Target	**10 m^2**	tgt_lineup_019a.wk	tgt_lineup_020a.wk	tgt_lineup_021a.wk
		tline0019a.mat	tline0020a.mat	tline0021a.mat
	0.1 m^2	tgt_lineup_019b.wk	tgt_lineup_020b.wk	tgt_lineup_021b.wk
		tline0019b.mat	tline0020b.mat	tline0021b.mat

2.2.3 Simulation Notes

During initial tests of this series no return appeared in the datacubes.   This was because the transmitter burn pulses (transmitted during the time it takes the first pulse to reach and return from the target/ground location) parameter was not set appropriately. Burn pulses are discussed in further detail in section 3.2.

When RLSTAP is started it uses US Geophysical Service (USGS) Digital Elevation Model (DEM) and Land Use/Land Cover (LULC) files located in the folder defined by the environment variable $USGS_DIR. When using the Ottawa scatterer field, this environment variable must be modified as described in section 4.2.

Due to the increased transmitter altitude (larger bistatic range) the slope of the Doppler over range was decreased compared to the slope observed in range-Doppler plots for the February 18 Series.

2.3 October 16 Series

2.3.1 Purpose

This series was designed so that the transmitter was no longer pointed straight down at the target. To accomplish this, the transmitter was shifted east and its elevation angle was adjusted accordingly. This was done to avoid an anomaly caused by pointing the antenna straight down. An alternate method of reducing the scatterer field memory requirements using tiles was compared to the reduced resolution scatterer field method.

2.3.2 Lineup Parameters

Table 5 shows only the parameters that were changed or added from the previous series lineups. Consult table 3 for the additional, unmodified parameters. As discussed previously, the Ottawa site-specific scatterer field relies on a 3 arc-second resolution material code file as a substitute for LULC information. To use this file at other resolutions it has to be resampled. For use with the tile method, the material code file was broken up into sections corresponding to the sections of the scatterer field that were generated (as shown in figure 3).

Table 5: Oct 16 Series Lineup Parameters

		Parameter	Value	Units
TX	**ANT**	Mech. AZ	-90	º (+CW from Yaw)
		Mech. EL	-85.42	º (-ve down from Pitch)
	PLAT	East Offset	800E3	m
CLUT		LAT NE Corner	46 (non-tiled)	º
		LAT SW Corner	45 (non-tiled)	º
		LONG NE Corner	-74 (non-tiled)	º
		LONG SW Corner	-76 (non-tiled)	º
		Resolution	9 & 3	Arc-seconds
		Type	Ottawa Site-Specific	
		Ottawa Material Code Rescale Factor	0.3335 & 1	
		Ottawa Material Code Tile Corner Origin	A:0,600; B:600,600; C:1200,600; D:1800,600; E:0,0; F:0,600; G:0,1200; H:0,1800	
		Ottawa Material Code Tile Sizes	600 x 600	
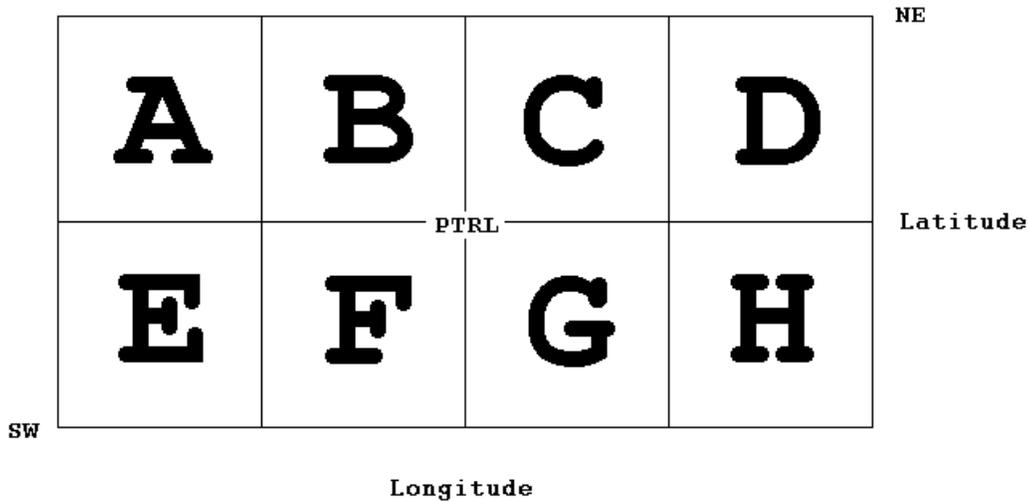
Figure 3: Scatterer Field Tiles

Table 6 lists the filenames used for the lineup files (*.wk) and the resulting datacube files (*.mat). The lineup and datacube filenames have a second letter appended to them representing tile regions shown in figure 3. If the filename does not have a second letter appended, the whole scatterer field was generated at reduced resolution. The clutter section of the table is divided according to resolutions 3 and 9 arc-seconds. The target section of the table is divided according to RCS values 0.1 and 10 m^2.

Table 6: Oct 16 Series Lineup (*.wk) and Datacube (*.mat) Filenames

		90	45	0
Ottawa Site-Specific Clutter	**9"**	int_noise_lineup_013 c.wk	int_noise_lineup_014 c.wk	int_noise_lineup_015 c.wk
		iline013c.mat	iline014c.mat	iline015c.mat
	3"	int_noise_lineup_013 ca-ch.wk	int_noise_lineup_014 ca-ch.wk	int_noise_lineup_015 ca-ch.wk
		iline013ca-ch.mat	iline014ca-ch.mat	iline015ca-ch.mat
Target	**10 m^2**	tgt_lineup_022a.wk	tgt_lineup_023a.wk	tgt_lineup_024a.wk
		tline0022a.mat	tline0023a.mat	tline0024a.mat
	0.1 m^2	tgt_lineup_022b.wk	tgt_lineup_023b.wk	tgt_lineup_024b.wk
		tline0022b.mat	tline0023b.mat	tline0024b.mat

2.3.3 Simulation Notes

After processing, the 3 arc-second (sum of tiles) range-Doppler maps were compared to the 9 arc-second maps. Little difference was found between the 9 and 3 arc-second results. The 3 arc-second scenarios take over eight times as long (for eight tiles) to run as the equivalent 9 arc-second scenario so the benefit of enhanced resolution does not outweigh the cost, in time, of the additional processing. If high resolution is required the scenario should use tiled processing due to memory limitations. Section 4 describes tiled and reduced resolution scatterer fields in more detail.

2.4 November 5 Series

2.4.1 Purpose

In this series, the transmitter platform position was adjusted to reduce its antenna grazing angle (to about 20 degrees). Like the February 18th series, the receiver and target offsets do not change with scenario. The transmitter is shifted so that its velocity vector is perpendicular to, parallel with, or intersecting at 45 degrees with the receiver velocity vector. The relative platform positions are as was shown in figure 1. Transmitter peak power was reduced and radiation frequency was increased. The transmitter and receiver antenna patterns were adjusted to increase the number of points but at reduced spacing (due to increased radiation frequency). Site-specific clutter from the Roswell, New Mexico area (centered on 34° Latitude, -107° Longitude) was also used for this series.

2.4.2 Lineup Parameters

Table 7 lists the main parameters used for the November 5th lineups. The table is separated into sections based on general simulation parameters (SIM), transmitter antenna (TX ANT) and platform parameters (TXPLAT), receiver antenna (RX ANT) and platform parameters (RX PLAT), target parameters (TGT), and clutter scatterer parameters (CLUT). In applicable cases, the parameter value column is split according to scenario (90, 45, and 0).

Table 7: Nov 5 Series Lineup Parameters

	Parameter	Value by Scenario			Units
		90	45	0	
SIM	CPIs	1			
	Pulses	32 + 87 burn pulses & 32 + 114 burn pulses			
	Sampling Rate	10E6			Hz
	Min Range Extent	5.01E6 & 6.52E6			m
	Max Range Extent	5.11E6 & 6.67E6			m

TX	**ANT**	H Array Points	200 & 600			
		H Points Spacing	0.15 & 0.05			m
		V Array Points	200 & 600			
		V Points Spacing	0.15 & 0.05			m
		Freq	1E9 & 3E9			Hz
		Mech. AZ	-90			° (+CW from Yaw)
		Mech. EL	-19.99			° (-ve down from Pitch)
		Peak Power	50E3			W
		PRI	390E-6			s
		PW	39E-6			s
		Burn Pulses	114			
	PLAT	Altitude	4465400			m
		LAT	45.5 & 34			°
		LONG	-75 & -107			°
		East Offset	12269E3	8675493	0	m
		North Offset	0	-8675493	-12269E3	m
		Velocity East	0	3158.6	4467	m/s
		Velocity North	4467	3158.6	0	m/s
		Yaw (Heading)	0	45	90	° (+ve CW from north)
RX	**ANT**	H Array Points	34 & 100			
		H Points Spacing	0.15 & 0.05			m
		V Array Points	5 & 15			
		V Points Spacing	0.15 & 0.05			m
		Freq	1E9 & 3E9			Hz
		Mech. AZ	-90			° (+CW from Yaw)
		Mech. EL	-9.37			° (-ve down from Pitch)
		Noise	0			dB
	PLAT	Altitude	19.5E3			m
		LAT	45.5 & 34			°
		LONG	-75 & -107			°
		East Offset	0			m
		North Offset	-100			m
		Velocity East	176.39			m/s
		Velocity North	0			m/s
		Yaw (Heading)	90			° (+ve CW from north)
TGT		Altitude	3E3			m
		LAT	45.5 & 34			°
		LONG	-75 & -107			°
		East Offset	0			m

	North Offset	0	m
	RCS	10 & 0.1	m^2
	Velocity East	0	m/s
	Velocity North	-138.89	m/s
	Yaw (Heading)	180	° (+CW from North)
CLUT	LAT NE Corner	46 & 34.5	°
	LAT SW Corner	45 & 33.5	°
	LONG NE Corner	-74 & -106	°
	LONG SW Corner	-76 & -108	°
	Resolution	9	Arc-seconds
	Type	Ottawa & Roswell Site-Specific	
	Ottawa Material Code Rescale Factor	0.3335	

Table 8 lists the filenames used for the lineup filenames (*.wk) and the resulting datacube filenames (*.mat). The target section of the table is separated according to RCS values 0.1 and 10 m^2

Table 8: Nov 5 Series Lineup (*.wk) and Datacube (*.mat) Filenames

		Freq (Hz)	90	45	0
Ottawa Site-Specific Clutter (9")		1E9	int_noise_lineup_016c.wk	int_noise_lineup_017c.wk	int_noise_lineup_018c.wk
			iline016c.mat	iline017c.mat	iline018c.mat
		3E9	int_noise_lineup_016e.wk	int_noise_lineup_017e.wk	int_noise_lineup_018e.wk
			iline016e.mat	iline017e.mat	iline018e.mat
Roswell Site-Specific Clutter (9")		1E9	int_noise_lineup_016d.wk	int_noise_lineup_017d.wk	int_noise_lineup_018d.wk
			iline016d.mat	iline017d.mat	iline018d.mat
		3E9	int_noise_lineup_016f.wk	int_noise_lineup_017f.wk	int_noise_lineup_018f.wk
			iline016f.mat	iline017f.mat	iline018f.mat
Target	10 m^2	1E9	tgt_lineup_025a.wk	tgt_lineup_026a.wk	tgt_lineup_027a.wk
			tline0025a.mat	tline0026a.mat	tline0027a.mat
		3E9	tgt_lineup_025c.wk	tgt_lineup_026c.wk	tgt_lineup_027c.wk

		tline0025c.mat	tline0026c.mat	tline0027c.mat
	1E9	tgt_lineup_025b.wk	tgt_lineup_026b.wk	tgt_lineup_027b.wk
0.1 m^2		tline0025b.mat	tline0026b.mat	tline0027b.mat
	3E9	tgt_lineup_025d.wk	tgt_lineup_026d.wk	tgt_lineup_027d.wk
		tline0025d.mat	tline0026d.mat	tline0027d.mat

2.4.3 Simulation Notes

As discussed previously, at startup RLSTAP uses USGS files located in the folder defined by the environment variable $USGS_DIR. When using the site-specific clutter scatterers glyph (SITE_SPECIFIC_SCAT) this environment variable should point to the location of the USGS files (default location for New Mexico, alternate location for Ottawa). See section 4.2 for more detail.

3 Simulation Range Space and Burn Pulse Testing

During testing, two problems prevented return from being seen in the RLSTAP datacubes. These problems were simulation range space limitations and burn pulse requirements.

3.1 Simulation Range Space Limitations

Transmitter altitude was initially limited based on an assumed RLSTAP limitation. Since Medium Earth Orbit (MEO) platform scenarios were desirable, this limitation was investigated. Tests were performed where the transmitter altitude was gradually increased until no scatters were detected in the High Fidelity Clutter Waveform Generator Prescan glyph (HIFI_CWG_PRESCAN). The resulting maximum altitude was used to calculate the bistatic range based on transmitter, receiver, and target positions. The bistatic range was compared to the Rmax setting in the SIMCON glyph and showed that no scatterers were generated when Rmax was less than half the bistatic range. To further test this the Rmin parameter was increased until no scatterers were detected. This occurred when Rmin was greater than half the bistatic range.

Upon further investigation formula 1 was found in the RLSTAP Interface Control Description (ICD) file simcon_detail.htm (McKay, 2003). This formula describes the simulation space limitations based on the simulation sampling frequency, the simulation space minimum and maximum ranges, and the conversion factor from distance to time (which is based on two-way range for a monostatic scenario).

$$nttl = 1.5 + \left(R_{max} - R_{min}\right) \times 6.671281E - 9 \times Fs \qquad (1)$$

Where:

nttl: number of simulation space samples (maximum of 262144 (256K) samples)
Rmax: simulation space maximum range (meters)
Rmin: simulation space minimum range (meters)
6.671281e-9: conversion factor from meters to seconds (2 way)
Fs: simulation sampling rate (Hz)

Rmin, Rmax, and simulation sampling frequency should be adjusted for each scenario to cover the area of interest but not exceed the maximum number of simulation space samples. For bistatic scenarios, Rmin should be set below half the lowest bistatic range and Rmax should be set higher than half the highest bistatic range. The simulation sampling frequency should be set as described in the following paragraph (while balancing the needs of range coverage and not exceeding the maximum number simulation space samples.

> "The frequency dimension of the simulation window is determined by the simulation sampling rate parameter (FS). Normally, the spectral width of the transmitted waveform will determine the minimum acceptable value of FS. If FS is too small, then frequency components greater than FS/2 will be folded into the sample space (aliased) and cause errors. The best approach to use in determining the sampling rate is to compute the spectrum of the transmitted waveform using a sampling rate that is at least an order of magnitude higher than the nominal bandwidth of the waveform. By observing the energy distribution in the frequency domain, the user can estimate the relative level of energy that is aliased based on various sampling rates" (Callaham & McKay, 2003, p. 25).

3.2 Burn Pulse Requirements

When MEO tests were initially attempted no return appeared in the datacubes.   After some investigation it was discovered that this was because the transmitter burn pulses parameter was not set appropriately in the TX_INIT glyph. The number of burn pulses must also be added to the total number of pulses in the SIMCON glyph. Burn pulses are "pulses sent out by the transmitter during the time required for the first transmit pulse to reach the furthest range of interest and be received. This so-called burn pulse interval contains transients and, usually, radar returns received during that time interval are thrown away, leaving the steady-state response." (Callaham & McKay, 2003, p. 27). The number of burn pulses is equal to the range ambiguity of the area of interest (where the area of interest is up to the maximum bistatic range). Therefore, the number of burn pulses should be set based on the formula:

$$N_{burn\_pulses} = \frac{\max(Rbis)}{c \times PRI} \qquad (2)$$

Where:

Nburn_pulses: number of burn pulses
Rbis: bistatic range of the area of interest (meters)
c: speed of light (m/s)
PRI: pulse repetition interval (seconds)

4 Tiled and Reduced Resolution Scatterer Fields Testing

Site-specific scatterer fields contain a large amount of data that taxes the memory and
storage capabilities of the system RLSTAP runs on. Two methods were developed to
reduce the memory requirements of the system and are discussed in section 4.1.
Depending on whether the Ottawa or a USGS supported site-specific scatterer field is
used, the $USGS_DIR environment variable must be modified. This issue is discussed in
section 4.2.

4.1 Reduction of Memory Requirements

Due to the large memory requirements of the site-specific clutter scatterer fields at 3 arc-
second resolution, the fields were either reduced to 9 arc-second resolution or broken into
tiles, which could be generated individually. Resolution and latitude/longitude corners
are set in the site-specific clutter glyph. The datacubes generated by the individual tile
runs could be summed and were processed as if the whole scatterer field was generated.

The tile method was tested by breaking the Ottawa site-specific scatterer field (at 9 arc-
second resolution) into eight tiles (as shown previously in figure 3). The Ottawa field
requires the material code file as a substitute for LULC information (see Hughes, 2002).
Since the material codes are at 3 arc-second resolution, they were resampled (using the
Khoros kresample glyph) and broken into tiles (using the Khoros kextract glyph)
corresponding to the scatterer field tile regions selected. Each of the tiles was processed
independently to generate datacubes using a 90-degree scenario. A datacube was also
generated using the whole field at 9 arc-second resolution for the same scenario. The
datacubes generated with each tile were summed and compared to the datacube generated
with the whole field. The power of the difference between the whole field result and
summed tile results ranges from 10 to 18 % of the power of the whole field result (see
equation 3).

$$\frac{\sigma^2_{whole-sum}}{\sigma^2_{whole}} = 0.1 \text{ to } 0.18 \tag{3}$$

Where variance (σ^2) in range is calculated for each (of 32) pulses

Due to the small differences it is possible to use the tile method and produce results that
are very similar to those produced by a whole scatterer field.

Table 9 lists the filenames used for the lineup filenames (*.wk) and the resulting datacube
filenames (*.mat). The lineup and datacubes filenames have a letter appended to the

filename representing tile regions shown in figure 3. If the filename does not have a letter appended, the whole scatterer field was generated.

Table 9: Reduced Resolution Tile Lineup (*.wk) and Datacube (*.mat) Filenames

	Lineup Filename	Datacube Filename
Whole Scatterer Field at 9" Resolution	int_noise_lineup_rres.wk	ilinerres.mat
Scatterer Field Tiles at 9" Resolution (8 Tiles)	int_noise_lineup_ rresa-h.wk	ilinerresa-h.mat

4.2 Site Specific Scatter File Locations

When RLSTAP is started it uses US Geophysical Service (USGS) Digital Elevation Model (DEM) and Land Use/Land Cover (LULC) files located in the folder defined by the environment variable $USGS_DIR. This environment variable is set in the user's .CSHRC file during installation. When using the Ottawa scatterer field, this environment variable should be changed to the location of the three files 'dummy.lulc', 'ottawa.dem', and 'ottawa.mc'. These files are currently located in the folder '/home/shughes/rlstap/usgs'. This change must be made and .CSHRC must be sourced before RLSTAP is started or the site-specific scatterer glyph will be unable to generate the Ottawa scatterer field. Note that the glyph will generate a blank field if this happens so the user is cautioned to verify the $USGS_DIR setting before starting RLSTAP. An easy way to check this is to type "echo $USGS_DIR" at the command line.

5 Pseudo Batch Processing

Once RLSTAP lineups have been prepared it is desirable to run them from the command line using a batch script. This was not initially possible due to a number of glyphs that continue to run even after the desired number of PRIs has been processed. These glyphs update simulation parameters that change from PRI to PRI and are called continuous-run or persistent glyphs.

The persistent glyphs used include:

- simcon: simulation controller
- hifi_cwg: high fidelity clutter waveform generator
- tgt_wvf_gen: target waveform generator
- antenna_server: antenna model servers
- add_noise: adds complex Gaussian noise to a waveform
- filtiira: infinite-duration impulse response (IIR) digital filter
- point_mass: point mass constant velocity platform model

Two possible solutions were investigated in an attempt to resolve the batch problem.

5.1 Sleep and Kill Method

To allow lineups to be run from the command line a workaround was developed which allowed batch processing using a combination of the sleep and kill UNIX commands on multiple simultaneous command lines. A shell script file was written for each lineup and each shell script was run on a separate command line. The shell scripts pause execution for a defined period, stop execution of CANTATA, clean up shared memory and temporary files, and execute the next lineup. The following seven lines (with modifications for sleep time and lineup filename) were placed in each shell script file.

```
sleep 5
ps -U bbrinson -o pid -o fname | awk '/cantata/ {print "kill "$1}' | /bin/sh
ps -U bbrinson -o pid -o comm | awk '/RLSTAP/ {print "kill "$1}' | /bin/sh
/flourine/rlstap/util/kseg
/flourine/rlstap_3.13/util/shmpurge
rm /tmp/io*
runwksp -hidden -silent -wksp int_lineup_018f.wk
```

The sleep command is given the number of seconds to suspend execution. This time should be set to allow a currently running lineup to generate its datacube. The time required varies with scenario so a user-supervised run may be required to obtain an estimate of run-time. On the second line, the ps command reports system processes. The –U flag reports processes owned by a specified user. The –o flag outputs the process id number when pid is specified and the first 8 bytes of the executable filename when fname is specified. The output of ps is piped to the awk command that searches for filenames containing the string 'CANTATA' and prints kill followed by the process id. This output is processed as a command therefore killing any processes having the string 'CANTATA' in its filename. The third line is used to kill any child processes whose command string contains the string 'RLSTAP'. These processes were orphaned when CANTATA was killed. The fourth line uses the kseg command to free up stranded, shared memory segments. The fifth line uses the shmpurge command (not available in RLSTAP version 1.8D) to clean up shared memory. This command was used because kseg does not reliably clean up shared memory. The sixth line removes temporary RLSTAP input/output files. The seventh line uses the run workspace (runwksp) command to execute the specified lineup. The hidden and silent flags prevent the CANTATA GUI from opening and suppress some status output respectively.

5.2 Encapsulated Workspaces

Investigations were made into encapsulated workspaces with the hope of producing batch executable workspaces. Encapsulated workspaces can be run without the CANTATA GUI. Encapsulated workspaces can also be used in CANTATA like any other glyph, with defined inputs and outputs. However, the encapsulated workspaces displayed the same behavior as if the workspace was run with runwksp. Control was again not returned at the command line after the desired number of PRIs had been processed. These investigations were abandoned in favor of the sleep/kill solution discussed previously.

For further detail refer to the Khoros v.2.20 CANTATA help documents file '12.encapwksp.doc' (not in MS Word format) located in the folder '/usr/local/khoros220/design/objects/xvroutine/cantata/help/'.

6 Datacube Processing and Range-Doppler Verification

The initial series of datacubes (Feb 18th) generated using RLSTAP were processed using two-dimensional Angle-Doppler Fast Fourier transforms (2DFFT) and Joint Domain Localized Space-Time Adaptive Processing (JDL-STAP) MATLAB routines supplied by the DRDC-O scientific authority. These routines were used to qualify target detection under various scenarios. For the later series, other MATLAB scripts were developed to verify the bistatic range and Doppler of the clutter and target results.

6.1 Datacube Processing

The February 18th series was processed using 2DFFT and JDL-STAP MATLAB routines. 2DFFT is a non-adaptive processing technique. The purpose of this processing is to qualify target detection in various scenarios.

Table 10 lists the MATLAB files that contain the processed results. Each file contains results for the 2DFFT, JDL-STAP with a local processing region (LPR) of 1x1 (Doppler bins x Angle bins), and JDL-STAP with a LPR of 3x3. Since ten Monte-Carlo runs (with varying clutter scatterers and noise) were processed, there are ten files for each clutter/target pair. The filenames have a letter appended (a through j) representing the Monte-Carlo run. A MATLAB script was later developed which took all ten datacubes as input, averaged the interference power, and output a single results file.

Table 10: JDL-STAP and 2DFFT Filenames

Filename	Clutter/Noise Datacube Used	Scenario (Angle)	Target Datacube Used	
jdl_2DFFT_results_001a-j.mat	iline001a-j.mat	90°	-10 dBsm Target	tline001.mat
jdl_2DFFT_results_002a-j.mat	iline002a-j.mat	45°		tline002.mat
jdl_2DFFT_results_003a-j.mat	iline003a-j.mat	0°		tline003.mat
jdl_2DFFT_results_004a-j.mat	iline001a-j.mat	90°	10 dBsm Target	tline004.mat
jdl_2DFFT_results_005a-j.mat	iline002a-j.mat	45°		tline005.mat
jdl_2DFFT_results_006a-j.mat	iline003a-j.mat	0°		tline006.mat

Each of the results files contains the following values (generated by JDL_2DFFT.M):

int_in: 2DFFT of interference before processing
IF_jdl: improvement factors for JDL STAP
sig_out_jdl: output signal power after JDL STAP
int_out_jdl: output interference power after JDL STAP

detections_jdl: detection map after JDL STAP and CFAR
udsf_jdl: usable Doppler-space fraction for JDL STAP
test_stats_jdl: output test statistics after JDL STAP
IF_2DFFT: improvement factors for non-adaptive processing
sig_out_2DFFT: output signal power after non-adaptive processing
int_out_2DFFT: output interference power after non-adaptive processing
detections_2DFFT: detection map after non-adaptive processing and CFAR
udsf_2DFFT: usable Doppler-space fraction for non-adaptive processing
test_stats_2DFFT: output test statistics after non-adaptive processing

Figures 4 through 8 are plots of the detection maps (detections_jdl and detections_2DFFT). The black areas represent areas where the target will not be detected. As shown in figure 4 versus 5 and figure 6 versus 7, the 10 dBsm target is detected over a larger area than the –10 dBsm target. A surprising result shown in figure 6 versus 8 is that a larger JDL-STAP LPR (figure 6 has LPR 1x1, figure 8 has LPR 3x3) did not improve target detection.

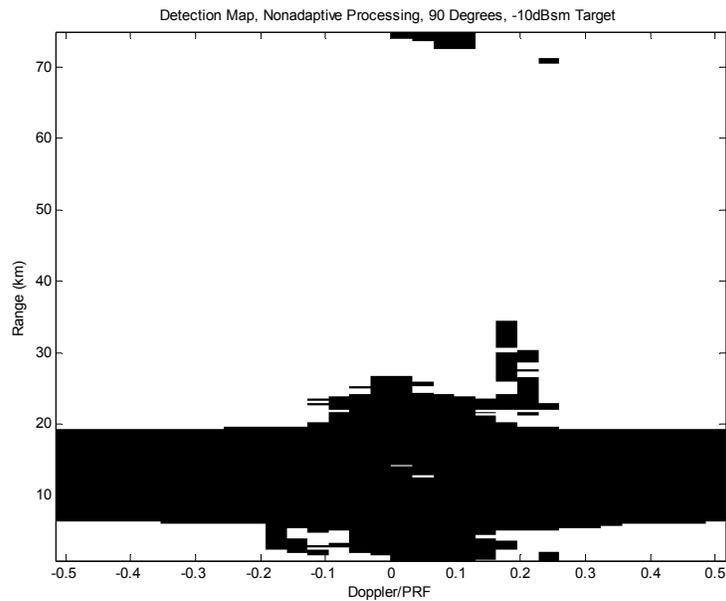**Figure 4: Detection Map, Non-adaptive Processing, 90 Degrees, -10 dBsm Target**

Detection Map, Nonadaptive Processing, 90 Degrees, 10 dBsm Target
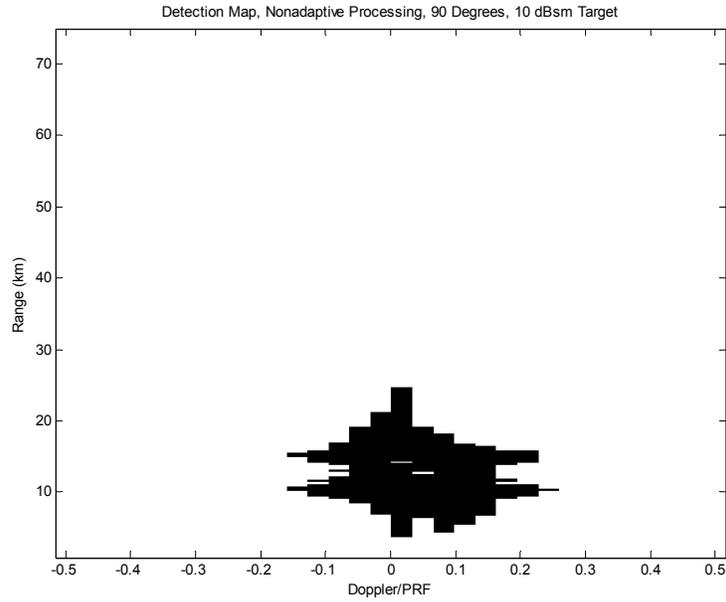
Figure 5: Detection Map, Non-adaptive Processing, 90 Degrees, 10 dBsm Target

Detection Map, JDL-STAP, LPR=1, 90 Degrees, -10dBsm Target
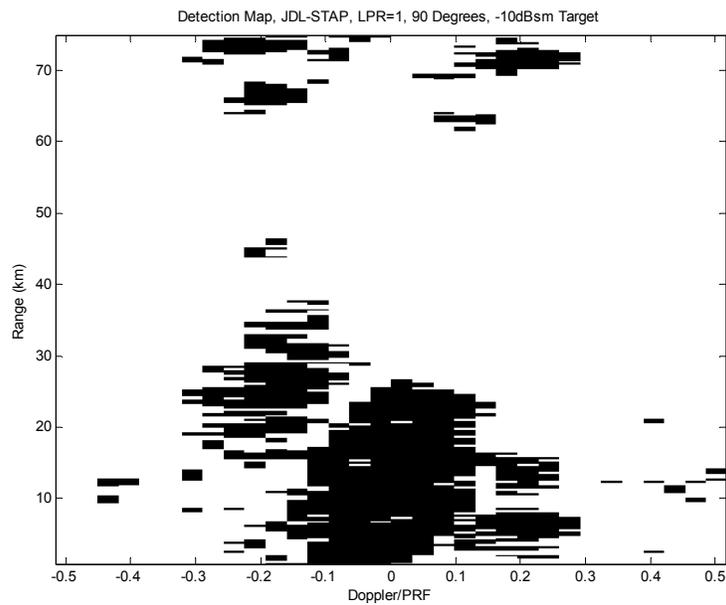
Figure 6: Detection Map, JDL-STAP, LPR=1x1, 90 Degrees, -10 dBsm Target

Detection Map, JDL-STAP, LPR=1, 90 Degrees, 10 dBsm Target
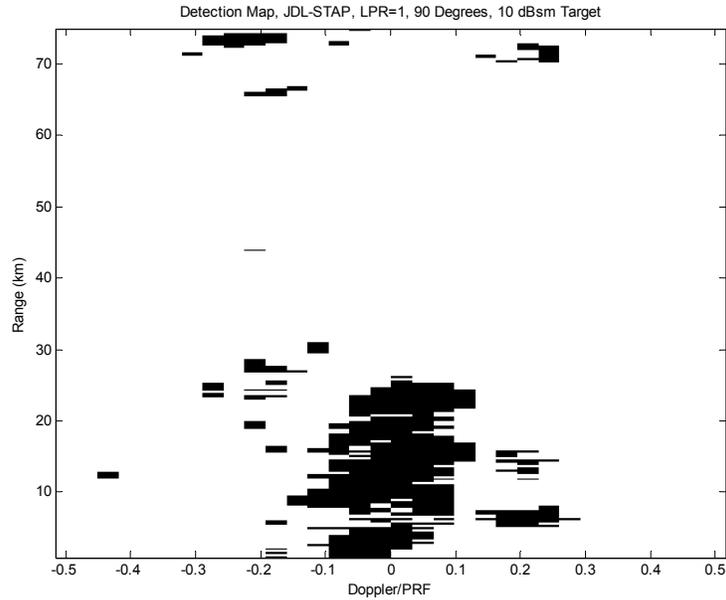
Figure 7: Detection Map, JDL-STAP, LPR=1x1, 90 Degrees, 10 dBsm Target

Detection Map, JDL-STAP, LPR=3, 90 Degrees, -10dBsm Target
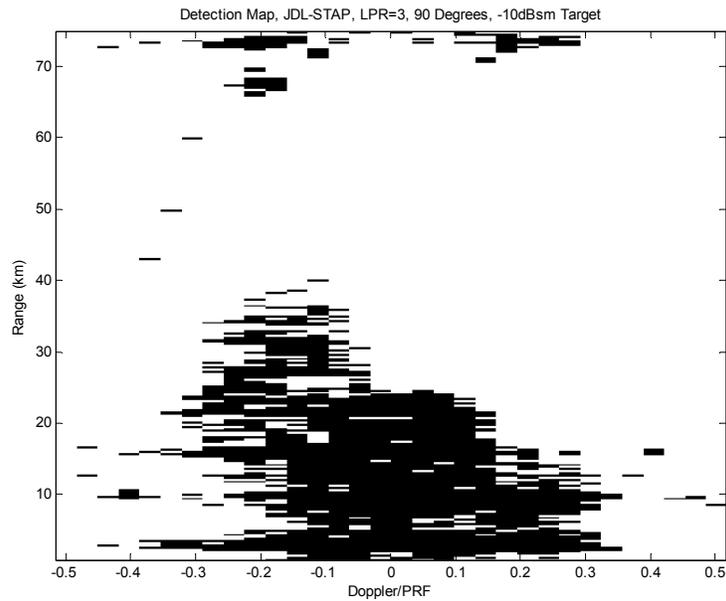
Figure 8: Detection Map, JDL-STAP, LPR=3x3, 90 Degrees, -10 dBsm Target

6.2 Range and Doppler Verification

MATLAB scripts were developed to verify the range and Doppler locations of targets and clutter in the datacubes produced using RLSTAP. These scripts calculate simulated bistatic range and Doppler for the various scenarios. The simulations are based on a

spherical earth model with radius 6367640 meters. This is the radius used by RLSTAP as specified in the user's manual (Callaham, 2003a, p.4). The calculated values were compared against those in the datacubes to verify results.

Bistatic range was calculated using the 3 dimensional positions of the transmitter, receiver, and target (or a clutter ground point). To calculate bistatic Doppler the transmitter, receiver, and target positions are first converted to Earth Centered/ Earth Fixed (ECEF) XYZ coordinates at several time intervals before and after time zero (the time at which all platforms are at their initial positions). The time window started at -0.1 seconds and ended at 0.1 seconds with time increments equal to the transmitter pulse repetition interval (PRI). This creates a bistatic range time series for each ground target or ground point that will be used to evaluate the bistatic Doppler for each of those targets/points. The bistatic Doppler at time zero for each point was calculated using a second order polynomial fit of the range series, resulting in equation 4.

$$Dopp_{Bis}(t=0) = \frac{\dot{r}}{\lambda} \tag{4}$$

Since

$$Dopp_{Bis} = \frac{\dot{\phi}}{2\Pi} \tag{5}$$

And

$$\phi = \frac{2 \cdot \Pi \cdot r}{\lambda} \tag{6}$$

Where

$$r = r_0 + \dot{r} \cdot t + \frac{\ddot{r}}{2} \cdot t^2 \tag{7}$$

The MATLAB simulation script was used to calculate the bistatic range and Doppler over the entire scatterer field by first dividing the field into a regular grid of rectangular cells. Each cell was treated as a target for which the bistatic range and Doppler was calculated. In order to increase the speed of the calculation, the algorithm used a fairly coarse grid at first, and a 2-D interpolation routine was then used to evaluate the range and Doppler on a finer grid. A sample is shown in figure 9. From the 2-D range and Doppler ground profile, a Range-Doppler map was generated for comparison with the RLSTAP simulations. The range-Doppler map was constructed by dividing the range-Doppler domain in rectangular cells of size given by the analytic resolution of the radar (i.e. based on the acquisition frequency and the number of pulses in one coherent processing interval (CPI)). Then each of the ground range-Doppler pairs is 'binned' in the range-Doppler map, adding an arbitrary value of one to the range-Doppler bins where it belongs. Thus, the resulting Range-Doppler map represents a count of the number of range-Doppler pairs falling in each range-Doppler bin. The counts depend on the size of ground cells chosen. Also, the effects of gain and antenna pattern are not modeled for the calculation. Therefore the actual results will not exactly match those from the calculated results.
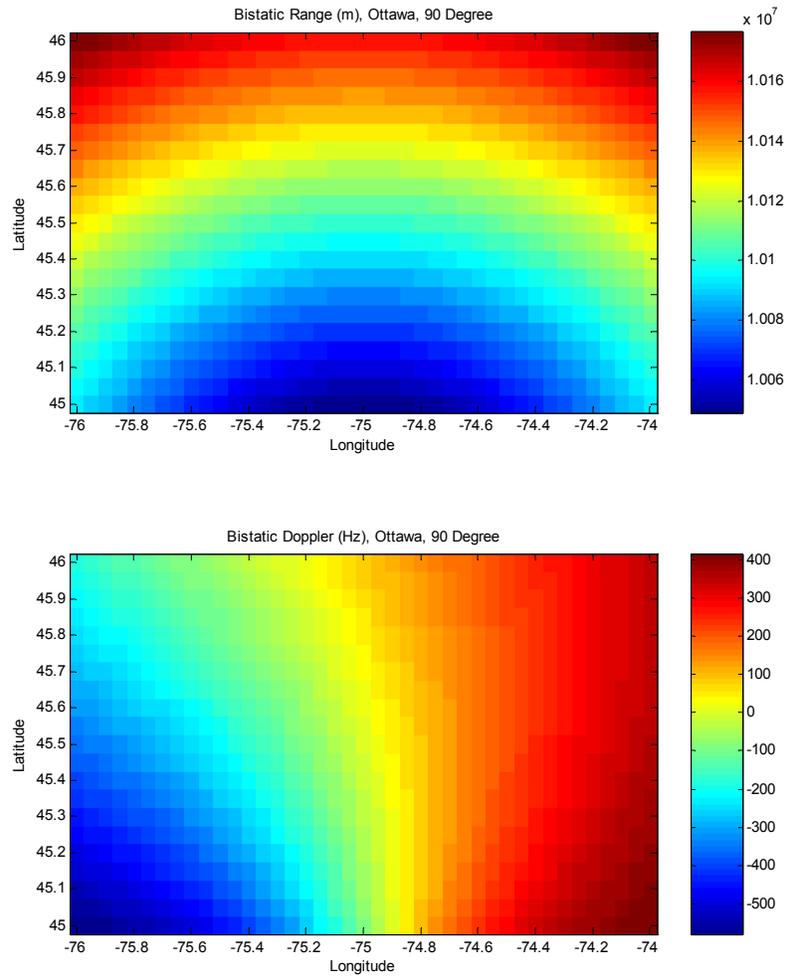
Figure 9: Bistatic Range and Doppler of Ottawa Scatterer Field, 90 Degree

Figures 10 and 12 show the range-Doppler maps (clutter and target respectively) of a MATLAB calculated result for a 90-degree scenario (June 19th series). Figures 11 and 13 show the range-Doppler maps (clutter and target respectively) obtained from a RLSTAP datacube of the same scenario. By comparing range-Doppler maps for several scenarios it was determined that RLSTAP was producing return for both clutter and targets in correct range-Doppler locations.
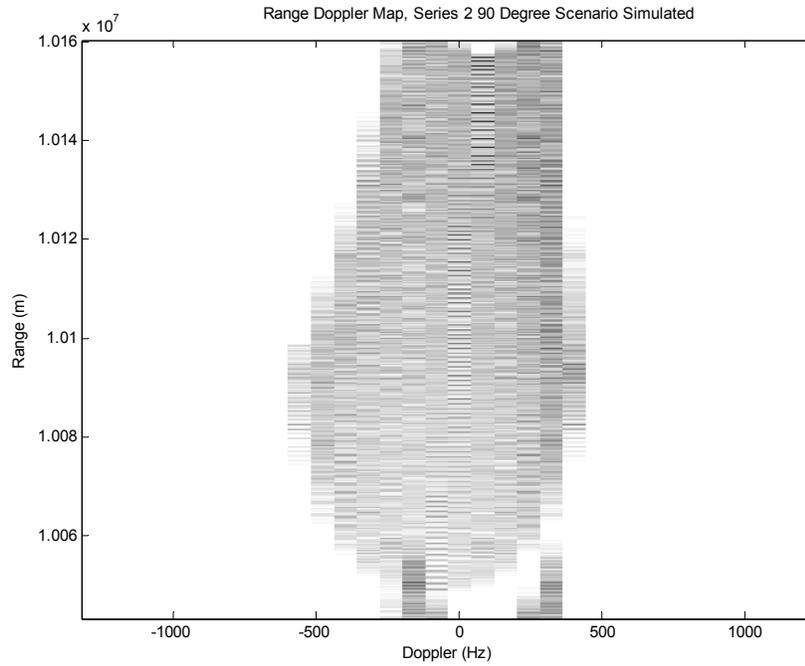
Figure 10: Clutter Range-Doppler Map, 90-Degree Scenario, MATLAB
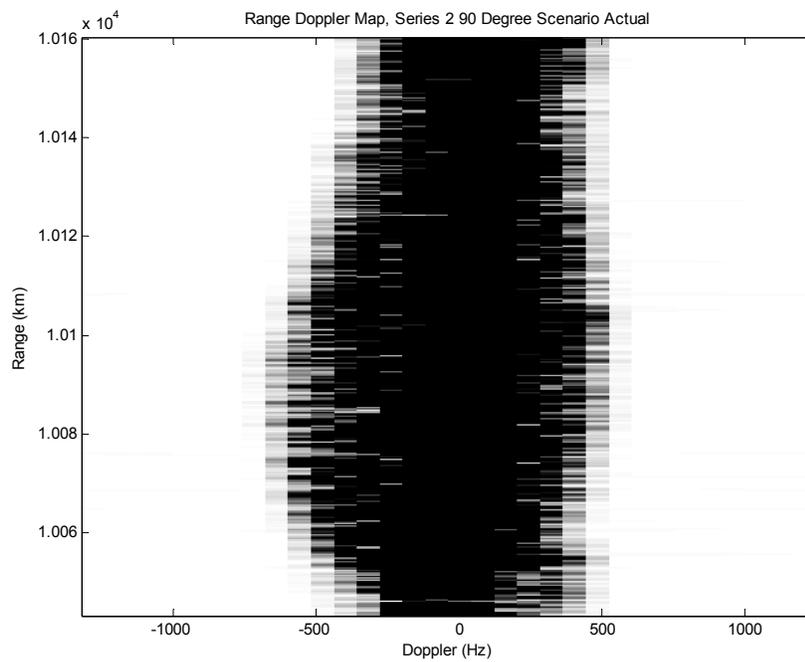
Figure 11: Clutter Range-Doppler Map, 90-Degree Scenario, RLSTAP
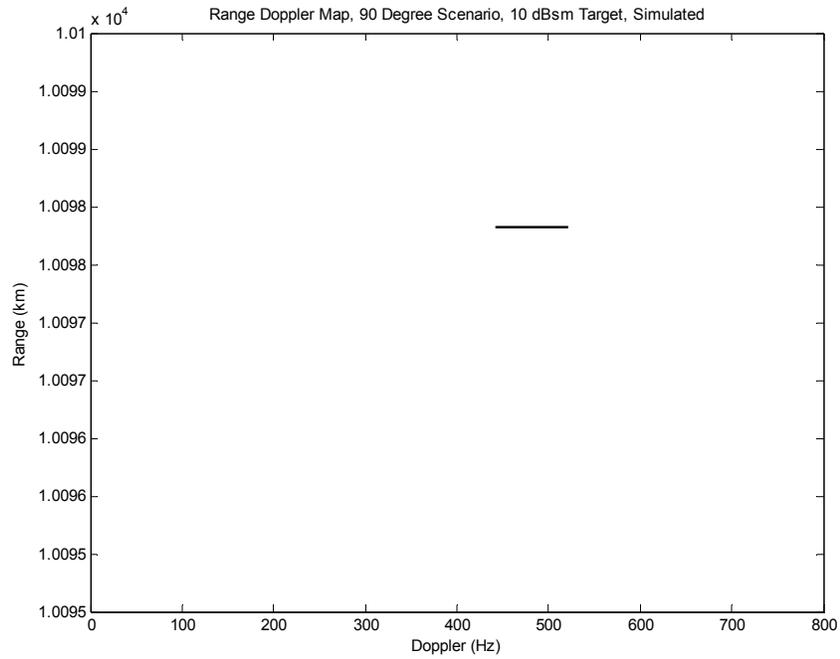
Figure 12: Target Range-Doppler Map, 90-Degree Scenario, MATLAB
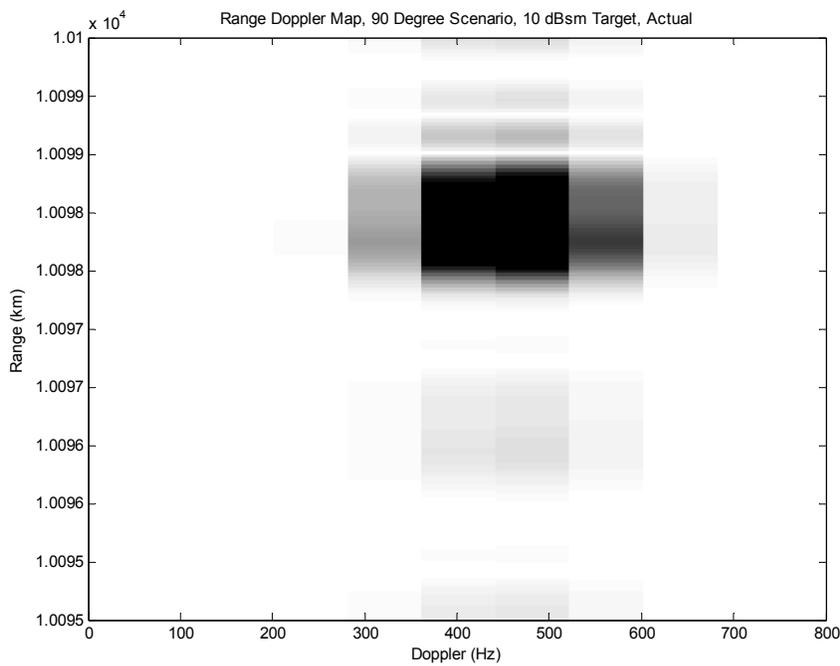
Figure 13: Target Range-Doppler Map, 90-Degree Scenario, RLSTAP

7 RLSTAP Tips and Cautions

This section lists a number of tips and cautions to keep in mind when developing RLSTAP lineups. A number of issues discussed in previous sections are reiterated here also. The RLSTAP FAQ (Callaham, 2003a) has additional tips and cautions not described in this report.

1. The kseg command (Callaham, 2003a, p.7) is provided with RLSTAP 3.18D to clear up stranded shared memory. Kseg should be frequently used to clear system swap space (being used by stranded shared memory). However, kseg does not reliably remove all stranded, shared memory, even when RLSTAP is no longer running. The command shmpurge (not available with RLSTAP 3.18D but available in 3.13) should be used to clear up shared memory left after kseg has been used. The /tmp folder should also be cleared often to prevent a lack of hard drive space due to the large number of input/output files produced by RLSTAP (Callaham, 2003a, p.7).

2. In the event that RLSTAP crashes, it is possible that several orphaned child processes will continue running. RLSTAP can be restarted but the orphaned processes will severely affect processing time. The kill command should be used to stop all of the orphaned processes, which have the string 'RLSTAP' in their command string (displayed when the ps command is used). Note that it is possible for processes to continue running even after the user logs out and logs into a new session.

3. The Rmin, Rmax, and simulation sampling rate parameters must be chosen carefully when preparing a lineup. These parameters are located in the SIMCON glyph and are limited by the number of simulation space samples as shown in equation 1 (section 3). Rmin should be set lower than half the lowest bistatic range and Rmax should be set larger than half the highest bistatic range. The simulation sampling rate should be set as described in section 3.

4. The number of burn pulses must also be set appropriately in the TX_INIT and SIMCON glyphs. Burn pulses are the pulses transmitted during the time it takes for the first transmitted pulse to travel to and return from the target or area of interest. The number of burn pulses can be determined using equation 2 (section 3).

5. The terrain visualization glyph (TVIS) can be used to visualize scatter fields on the ground in latitude/longitude coordinates. The output of the site-specific and homogenous scatterer field glyphs can be plotted using TVIS. Alternatively, the output of the high fidelity clutter prescan glyph (HF_CWG_PRESCAN) can be input to incorporate the effects of Sigma0, grazing angle elements, thresholding, and shadowing. Gain contours of the transmitter and receiver antennas can also be plotted over the scatter region to visualize ground regions falling within the mainbeam of the antenna patterns. The MONO_CLU_PARM glyph must be used for additional input in this case to generate transmitter, receiver, target, and clutter parameters in longitude vs. latitude coordinates. When plotting antenna gain contours it is best to use the 'Contour from Peak Value' option. This option will contour values (in this

case, gain values) from the peak down to peak minus a specified number of decibels. To plot only the highest gain section of the antenna pattern (most of the mainlobe) the number of decibels should be set to 1. A sample contour plot (with limits of peak down 1 dB) is shown in figure 14. Decreasing the lower gain limit plots more of the lower power sections of the antenna pattern, including the sidelobes if they intersect the ground. Figure 15 shows a contour plot where the lower limit is peak down 40 dB. By increasing the number of contour lines parameter the resolution of the contours increases. The option 'Contour Evenly' should be avoided because it divides the entire range of gain values evenly, by the number of contour lines specified. At low altitudes, many of the antenna sidelobes are visible within the scatterer field area, increasing the range of gain values, therefore increasing the range of values shared in the mainlobe contour. Figure 16 shows a contour plot in which the receiver is at low altitude and the lower limit is set peak down 60 dB. A large number of sidelobes are apparent. TVIS contours are described further in the RLSTAP interface control document (McKay, 2003, tvis-contour.htm).
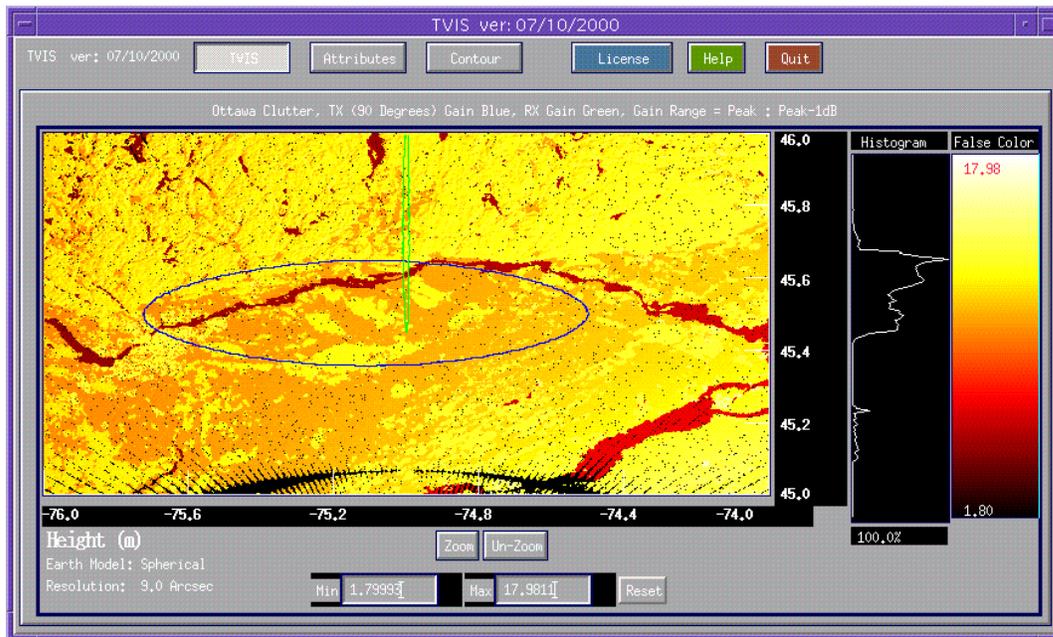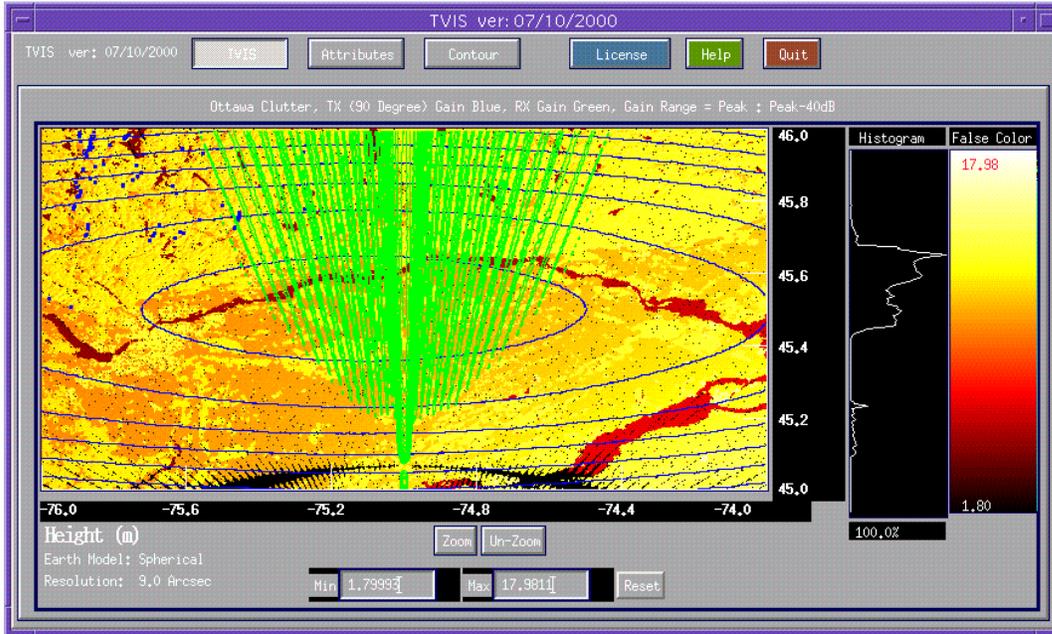

Figure 14: Antenna Gain Contours (Peak:Peak-1dB)

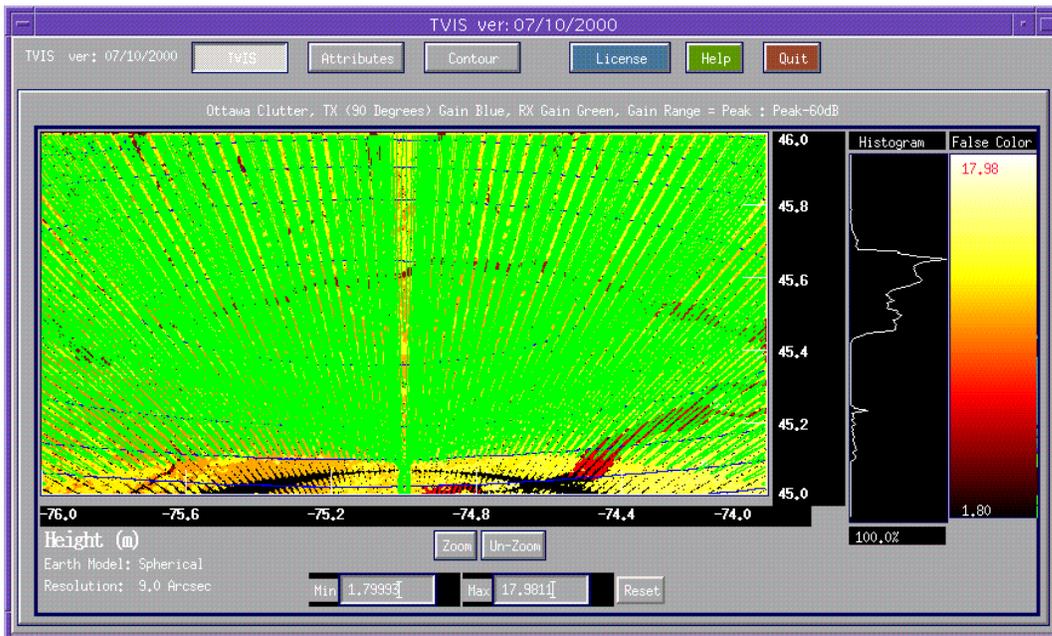**Figure 15: Antenna Gain Contours (Peak:Peak-40dB)**

Figure 16: Antenna Gain Contours (Peak:Peak-60dB)

6. When RLSTAP is started it uses it uses US Geophysical Service (USGS) Digital Elevation Model (DEM) and Land Use/Land Cover (LULC) files located in the folder defined by the environment variable $USGS_DIR. Since the USGS files that RLSTAP requires to generate scatterer fields are only available for US locations, a special process is required to produce scatterer fields for the Ottawa area. This process is described in a DRDC-O report written by Steven Hughes (2002). This environment variable is set in the user's .CSHRC file during installation. When using the Ottawa scatterer field, this environment variable should be changed to the location of the three files 'dummy.lulc', 'ottawa.dem', and 'ottawa.mc'. These files are currently located in the folder '/home/shughes/rlstap/usgs'. This change must be made and .CSHRC must be sourced before RLSTAP is started or the site-specific scatterer glyph will be unable to generate the Ottawa scatterer field. Note that the glyph will generate a blank field if this happens so the user is cautioned to verify the $USGS_DIR setting before starting RLSTAP. An easy way to check this is to type "echo $USGS_DIR" at the command line. The Ottawa material code file (ottawa.mc) has been generated at 3 arc-second resolution (2400x1200 points) and must be resampled to match an alternate resolution setting in the site-specific scatterer glyph. For example, if 9 arc-second resolution is chosen the material code should be resampled by 33% (resulting in 800x400 points).

7. When shifting glyphs and input/output ports within the CANATA GUI, it is possible that ports may become overlapped. It is not possible to select and move single ports so there is no way to select or move the underlying port from within the GUI editor. Since the lineup files are saved in ASCII text format it is possible to shift glyph and port positions with a text editor. All glyphs, ports, procedures, etc. have a specific format which includes x and y positions. Modifying these positions make it possible to shift an overlapped port. The following lines describe the format of objects in a lineup file. Local host refers to the location of the object such as in a procedure or loop, or at the top workspace level. No two objects in the same local host can have the same assigned number. In the following list, 'Assigned_Name', Assigned_Port_#, and 'Assigned_#' are user assigned.

Glyph
Glyph_Name:Toolbox:Assigned_Name:localhost:Assigned_#:X_Pos:Y_Pos::Flags

Procedure
ProcedureBegin:Assigned_Name:(unknown):localhost:Assigned_#: X_Pos:Y_Pos:
PROCEDURE CONTENTS
ProcedureEnd:Assigned_Name

Loop
LoopBegin:Assigned_Name:While_OR_Count:localhost:Assigned_#:X_Pos:Y_Pos:flags
LOOP CONTENTS
LoopEnd:Assigned_Name

External Port
ExtPort:In_OR_Out:Assigned_Name:ICD_Port_Name:Assigned_Port_#:X_Pos:Y_Pos:

Node Connection
NodeConnection:Data_OR_Control:Output_Glyph_OR_ExtPort_#:Output_Glyph_Port_
Name_(Empty_If_ExtPort):Input_Glyph_OR_ExtPort_#:Input_Glyph_Port_Name_(Emp
ty_If_ExtPort):

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List of Symbols, Abbreviations, and Acronyms

2DFFT	Two Dimensional Angle-Doppler Fast Fourier Transform
BISTAP	Bistatic Space-Time Adaptive Processing
CPI	Coherent Processing Interval
DEM	Digital Elevation Model
DRDC	Defence R&D Canada
GUI	Graphical User Interface
ICD	Interface Control Document (RLSTAP)
JDL-STAP	Joint Domain Localized Space Time Adaptive Processing
LPR	Localized Processing Region
LULC	Land Use/Land Cover
MEO	Medium Earth Orbit
PRI	Pulse Repetition Interval
PTRL	Platform Trajectory Reference Location
PW	Pulse Width
RCS	Radar Cross Section
RLSTAP	Research Laboratory Space-Time Adaptive Processing
STAP	Space-Time Adaptive Processing
USGS	US Geophysical Service

APPENDIX A: Toolbox, Glyph, and Parameter Names

The following table can be used to determine the toolbox, glyph, and glyph parameter names for the general parameter names used throughout the tables in this report. The parameters have been sorted by general function into sections SIM (simulation), TX (transmitter antenna ANT and platform PLAT), RX (receiver antenna ANT and platform PLAT), TGT (target), and CLUT clutter).

		Parameter	Toolbox	Glyph Name	Glyph Parameter Name
SIM		CPIs	a_controllers	simcon	n_cpi
		Pulses			n_txpls
		Sampling Rate			fs
		Min Range Extent			rngmin
		Max Range Extent			rngmax
TX	**ANT**	H Array Points	a_design_synthesis	gen_lin_array	npts
		H Points Spacing			elemspac
		V Array Points			npts
		V Points Spacing			elemspac
		Freq	a_design_synthesis	elem_ctrl	freq
			a_hardware_emulators	tx_init	f_tx_hz
			a_hardware_emulators	antenna_server	fc, fi, fo
		Mech. AZ	a_hardware_emulators	antenna_server	maz
		Mech. EL			mel
		Peak Power	a_hardware_emulators	tx_init	peak_pwr_watts
		PRI			pri_sec
		PW			pw_tx_sec
		Burn Pulses			n_burn_pulses
	PLAT	Altitude	a_scenario_generators	point_mass	altitude
		LAT			xlatov
		LONG			xlngov
		East Offset			ylocv
		North Offset			xlocv
		Velocity East			yvelv
		Velocity North			xvelv
		Yaw (Heading)			yaw
RX	**ANT**	H Array Points	a_design_synthesis	gen_lin_array	npts
		H Points Spacing			elemspac
		V Array Points			npts
		V Points Spacing			elemspac
		Freq	a_design_synthesis	elem_ctrl	freq
			a_hardware_emulators	antenna_server	fc, fi, fo
		IF Filter BW	a_hardware_emulators	rx_init	if_filt_bw
		Mech. AZ	a_hardware_emulators	antenna_server	maz
		Mech. EL			mel
		Noise	a_hardware_emulators	rx_init	noise_fig_db
	PLAT	Altitude	a_scenario_generators	point_mass	altitude
		LAT			xlatov
		LONG			xlngov
		East Offset			ylocv

		North Offset			xlocv
		Velocity East			yvelv
		Velocity North			xvelv
		Yaw (Heading)			yaw
TGT	Altitude	a_scenario_generators	point_mass	altitude
	LAT			xlatov
	LONG			xlngov
	East Offset			ylocv
	North Offset			xlocv
	Velocity East			yvelv
	Velocity North			xvelv
	Yaw (Heading)			yaw
	RCS	a_environment_generators	tx_init	rcs_mean
CLUT	LAT Increment	a_phenomenology	homo_scat	lat_inc
	LAT NE Corner	a_phenomenology	site_specific_scat OR homo_scat	ne_lat
	LAT SW Corner			sw_lat
	LONG Increment			long_inc
	LONG NE Corner			ne_long
	LONG SW Corner			sw_long
	Resolution	a_phenomenology	site_specific_scat	point_resolution
	Ottawa Material Code Rescale Factor	datamanip	kresample	wmag AND hmag
	Scatterer Field Tile Origin Corner	datamanip	kextract	woff AND hoff
	Scatterer Field Tile Sizes			wsize AND hsize

APPENDIX B: Scenario Independent Lineup Parameters

The following parameters had the same value for all of the RLSTAP lineups tested. The parameters have been sorted by general function into sections SIM (simulation), TX (transmitter antenna ANT and platform PLAT), RX (receiver antenna ANT and platform PLAT), TGT (target), and CLUT clutter).

		Parameter	Toolbox	Glyph Name	Glyph Parameter Name	Value
SIM		tx waveform oversample ratio	a_controllers	simcon	ldec	4
		cpi length (s)			cpi_length	1
		sim start time (s)			sim_start_time	0
		tx cycle loop	a_controllers	cpicon		
		range-channel to range-channel-pulse	a_data_manip	rc_to_rcp		
		range fold waveform	a_environment_generators	rng_fld_wvf		
		pulse compression	a_digitial_signal_processing	decprbsa	noclr	1 (clear accumulators between each transmit pulse)
TX	**ANT**	tx rf loss (dB)	a_hardware_emulators	tx_init	tx_rf_loss_db	0
		array orientation	a_design_synthesis	gen_lin_array	orient	1 (H) OR 2 (V)
		linear Taylor weighting			w5	flag, no value
		peak sidelobe level (dB)			dbmlsl	50
		# of zeros			nbar	8
		beam steer phase shift accuracy	a_design_synthesis	elem_ctrl	nbits	10
		beam steer in az/el coords			s	flag, no value
		az mainbeam center angle (°)			az	0
		el mainbeam center angle (°)			el	0
		# horizontal subapertures	a_design_synthesis	gen_sub_apertures	nh	8
		# vertical subapertures			nv	1
		horizontal subaperture spacing (m)			dh	0.4
		vertical subaperture spacing (m)			dv	1
		generate rectangular array	a_design_synthesis	gen_rect_array		
		peak directive gain at boresight (dBi)	a_hardware_emulators	antenna_server	pkgn	60
		phase shifter quantization			n_bits	10
		power in cos(theta)^pow			cpower	0.6

		ESA Beam steering command X-coordinate (k-space)			xb	0
		ESA Beam steering command Y-coordinate (k-space)			yb	0
		antenna look-up table (LUT) using FFT model			lut	flag, no value
		X axis center of transform output area (k-space)			xc	0
		X axis span of transform output area (k-space)			xs	2
		antenna pattern interpolation method default			imode	1 (bicubic spline)
		2D transform width (power of 2)			n2h	10
		Y axis center of transform output area (k-space)			yc	0
		Y axis span of transform output area (k-space)			ys	2
		2D transform height (power of 2)			n2v	10
		switching time between subpulses (s)	a_hardware_emulators	gen_pc_wvf	swtim_sec	0.5E-6
		phase encoder type			iphm	1 (binary)
		# stages in shift register			nsr	2
		shift register initial value			ipy	1
		data object-specified phase encoder mode	a_hardware_emulators	gen_pc	do	flag, no value
		Barker code			modeph1	flag, no value
		# subpulses			nsubp_1	13
	PLAT	roll (º)	a_scenario_generators	point_mass	roll	0
		pitch (º)			pitch	0
		down velocity (m/s)			zvelv	0
RX	ANT	receiver rf losses (dB)			rx_rf_loss_db	0
		if filter 3 dB bandwidth (Hz)			if_filt_bw	1E6
		turn-on time in current PRI (s)	a_hardware_emulators	rx_init	rx_on	0
		turn-off time in current PRI (s)			rx_off	PRI
		est main beam clutter Dopp shift (Hz)			est_mbc_Dopp_freq_hz	0
		array orientation			orient	1 (H) OR 2 (V)
		linear Taylor weighting	a_design_synthesis	gen_lin_array	w5	flag, no value
		peak sidelobe level			dbmlsl	30
		# of zeros			nbar	8
		beam steer phase shift accuracy	a_design_synthesis	elem_ctrl	nbits	10
		beam steer in az/el coords			s	flag, no value

		az mainbeam center angle			az	0
		el mainbeam center angle			el	0
		peak directive gain at boresight (dBi)			pkgn	60
		phase shifter quantization			n_bits	10
		power in cos(theta)^pow			cpower	0.6
		ESA Beam steering command X-coordinate (k-space)			xb	0
		ESA Beam steering command Y-coordinate (k-space)			yb	0
		antenna look-up table (LUT) using FFT model			lut	flag, no value
		X axis center of transform output area (k-space)	a_hardware_emulators	antenna_server	xc	0
		X axis span of transform output area (k-space)			xs	2
		antenna pattern interpolation method default			imode	1
		2D transform width (power of 2)			n2h	10
		Y axis center of transform output area (k-space)			yc	0
		Y axis span of transform output area (k-space)			ys	2
		2D transform height (power of 2)			n2v	10
		generate rectangular array	a_design_synthesis	gen_rect_array		
		add complex Gaussian noise	a_hardware_emulators	add_noise	autoseed	flag, no value
		# poles in transfer function			np	8
		filter loss at pass-band center (dB)			filtloss_db	0
		Butterworth filter	a_hardware_emulators	filtiira	ntypef_1	flag, no value
		low-pass filter			filter_type_1	flag, no value
		accumulator reset control			noclr	2 (do not clear after first pulse)
	PLAT	roll (°)	a_scenario_generators	point_mass	roll	0
		pitch (°)			pitch	0
		down velocity (m/s)			zvelv	0
TGT		roll (°)	a_scenario_generators	point_mass	roll	0
		pitch (°)			pitch	0
		down velocity (m/s)			zvelv	0
		RCS correlation time (s)	a_environment_generators	tgt_init	rcs_corr_time	0.1

	non-fluctuating target model			rcs_fluct_indx_0	flag, no value
	autoseed	a_environment_ge nerators	tgt_wvf_gen	autoseed	flag, no value
CLUT	polarization			ipol	1 (H)
	grazing angle increment (º)			ginc	0.1
	terrain type			tt	3 (agriculture)
	season	a_phenomology	rss_sigma0_curve	sn	1 (spring)
	terrain clutter strength relative to the mean backscatter			cs	1 (normal)
	sea state			ss	1 (state 0)
	land surface			land	flag, no value
	grazing angle increment (º)			ginc	0.1
	five parameter scattering coefficient model			sm2	flag, no value
	plateau	a_phenomology	sigma0_curve	c0	0.0016
	constant gamma coefficient			c1	0.158
	exponential multiplier			c2	10
	incidence angle multiplier			c3	0.262
	exponent			c4	1.32
				ginc	0.1
	ERAM scattering coefficient model	a_phenomology	sigma0_curve	sm1	flag, no value
	freq band			fband	1 (X band)
	sea state			turf	1 (state 1)
	autoseed			autoseed	flag, no value
	standard deviation of randomization factor	a_phenomology	site_specific_scat	sd_ran_fac	0.2
	random scatterer locations			rnd	flag, no value
	material code			mc	3
	random scatterer locations	a_phenomology	homo_scat	rnd	flag, no value
	autoseed			autoseed	flag, no value
	convolution method	a_environment_ge nerators	hifi_cwg	conv	1 (brute force)
	tx gain threshold (dBI)			txgt	100
		datamanip	kextract	subpos	0
		datamanip	kmul	real	0
				append	1
		datamanip	kappend	mapping	0
				d	flag, no value
	depth			dsize	32
	width offset			woff	0
	height offset	datamanip	kextract	hoff	0
	depth offset			doff	0
				subpos	0
		datamanip	kresample	dmag	1
				tmag	1

				emag	1
				inter	0
				resize	1
				center	flag, no value
				arch	1
				type	3
width				wsize	2400
height				hsize	1200
depth				dsize	1
				tsize	1
	datamanip	kimportraw		esize	1
				skip	0
				segment	1
				color	1
				-i1	/home/shughes/rlstap/usgs/ottawa.mc

APPENDIX C: Lineup Glyph Organization

The following listing shows the organization of glyphs within the RLSTAP lineups that were tested. Glyph names and toolboxes are listed but glyph parameters are not. Level of indentation represents nesting.

WorkspaceBegin

      Glyph:A_RADAR_ANALYSIS:mono_clu_parm
      Glyph:A_ENVIRONMENT_GENERATORS:hifi_cwg_prescan
      Glyph:A_CONTROLLERS:simcon:
      Glyph:A_INPUT_OUTPUT:kdf_to_mat
      Glyph:A_DIGITAL_SIGNAL_PROCESSING:filtpdaary

      ProcedureBegin:SIGMA0 LUT
            Glyph:A_PHENOMENOLOGY:sigma0_lut
            Glyph:A_PHENOMENOLOGY:rss_sigm0_curve
            Glyph:A_PHENOMENOLOGY:sigma0_curve
      ProcedureEnd:SIGMA0 LUT

      ProcedureBegin:INITIALIZATION
            Glyph:A_SCENARIO_GENERATORS:point_mass
            Glyph:A_ENVIRONMENT_GENERATORS:tgt_init
            Glyph:A_CONTROLLERS:plat_collector
            Glyph:A_HARDWARE_EMULATORS:tx_init
            Glyph:A_HARDWARE_EMULATORS:rx_init
            Glyph:A_DESIGN_SYNTHESIS:gen_lin_array
            Glyph:A_DESIGN_SYNTHESIS:elem_ctrl
            Glyph:A_DESIGN_SYNTHESIS:gen_sub_apertures
            Glyph:A_DESIGN_SYNTHESIS:gen_rect_array
            Glyph:A_HARDWARE_EMULATORS:antenna_server
      ProcedureEnd:INITIALIZATION

      ProcedureBegin:TX WAVEFORM GENERATOR
            Glyph:A_HARDWARE_EMULATORS:gen_pc_wvf
            Glyph:A_HARDWARE_EMULATORS:gen_pc
      ProcedureEnd:TX WAVEFORM GENERATOR

      LoopBegin:PRI LOOP

            ProcedureBegin:COHERENT SIGNAL PROCESSING
                  Glyph:A_DIGITAL_SIGNAL_PROCESSING:decprbsa
            ProcedureEnd:COHERENT SIGNAL PROCESSING

            ProcedureBegin:RECEIVER MODEL
                  Glyph:A_HARDWARE_EMULATORS:add_noise
                  Glyph:A_HARDWARE_EMULATORS:filtiira
            ProcedureEnd:RECEIVER MODEL

            ProcedureBegin:PHYSICAL MODEL
                  Glyph:A_ENVIRONMENT_GENERATORS:tgt_wvf_gen
                  Glyph:A_ENVIRONMENT_GENERATORS:rng_fld_wvf
                  Glyph:A_ENVIRONMENT_GENERATORS:hifi_cwg

          Glyph:DESIGN:user_def
      ProcedureEnd:PHYSICAL MODEL

      Glyph:A_CONTROLLERS:cpicon
      Glyph:A_DATA_MANIP:rc_to_rcp

LoopEnd:PRI LOOP

Glyph:DATAMANIP:kextract
Glyph:DATAMANIP:kmul
Glyph:DATAMANIP:kappend
Glyph:DATAMANIP:kextract
Glyph:DATAMANIP:kresample
Glyph:DATAMANIP:kimportraw
Glyph:A_PHENOMENOLOGY:site_specific_scat
Glyph:A_PHENOMENOLOGY:homo_scat

WorkspaceEnd

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DRDC Ottawa is using the RLSTAP Simulation Tool to execute bistatic radar scenarios and investigate bistatic data signal processing. This report is meant to track the testing performed by Vantage Point International Inc. under standing offer W7714-1-0566. The focus of this testing was to verify RLSTAP operation under various scenarios, resolve any problems discovered when generating these scenarios, and verify bistatic range and Doppler placement of clutter and target returns. The main areas covered in this report are homogeneous and site-specific clutter including Ottawa, Ontario and Roswell, New Mexico, reduced resolution clutter support, MEO (Medium Earth Orbit) scenarios, batch script support, and two-dimensional Angle-Doppler Fast Fourier Transform and Joint Domain Localized Space-Time Adaptive Processing (JDL-STAP). A number of tips and cautions were noted during testing and would be helpful to RLSTAP users.

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radar simulation, space-based radar, space-time adaptive processing