Data Distribution Tool - Documentation and User's Manual

Vince Mantle

Prepared by:

MacDonald, Dettwiler and Associates Ltd.
13800 Commerce Parkway, Richmond, B.C., Canada, V6V 2J3

Prepared for:

Project Manager: Edwin Riseborough 613-998-2052
Contract Number: W7714-135828/001/SV
Technical Authority: David Kirkland
DRDC – Ottawa Research Centre, 613-949-0552

Contract Report
DRDC-RDDC-2016-C311
January 2016

CHANGE RECORD

ISSUE	DATE	PAGE(S)	DESCRIPTION
0/0	Jan 07, 2016	All	First DRAFT Issue

TABLE OF CONTENTS

1 INTRODUCTION 1-1
1.1 Background 1-1
1.2 Purpose 1-1
1.3 Structure of Document 1-2

2 DOCUMENTS 2-1
2.1 Applicable Documents 2-1
2.2 Reference Documents 2-1

3 XWEAR RAW DATA DISTRIBUTION TOOL 3-1
3.1 Introduction 3-2
3.1.1 Target Coordinate System and Range-Compression 3-2
3.1.2 Antenna Configuration 3-4
3.1.3 Range Shift between the Two Channels 3-5
3.2 Inputs 3-6
3.2.1 Input Argument List 3-7
3.2.2 Configuration Parameters File. 3-7
3.3 Outputs 3-11
3.3.1 Range Compressed Data 3-11
3.3.2 Information record 3-11
3.3.3 Additional Outputs 3-12
3.4 Example of Tool Usage 3-13

4 XWEAR IMAGERY DATA DISTRIBUTION TOOL 4-1
4.1 Introduction 4-1
4.1.1 Input Arguments 4-2
4.1.2 Output Arguments 4-2
4.2 Example of Tool Usage 4-3

A HEADER RECORD 4-5

B ANCILLARY DATA RECORD 4-12

LIST OF FIGURES

Figure 3-1 Target Coordinate System, with left-looking radar illustrated. 3-2
Figure 3-2 X-shifted Target Coordinate System (so that origin coincides with target location); diagram illustrates a left looking radar example. 3-3
Figure 3-3 Output Swath Width and Processed Range-Bandwidth 3-9

ACRONYMS AND ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
APC	Antenna Phase Centre
CP140	Canadian Patrol aircraft 140, also known as the Aurora
DRDC	Defence Research and Development Canada
FFT	Fast Fourier Transformation
HH	Horizontal polarization on transmit, horizontal polarization on receive
HV	Horizontal polarization on transmit, vertical polarization on receive
MATLAB	Matrix Laboratory software package from Mathworks Inc.
MDA	MacDonald, Dettwiler and Associates Ltd.
RCMC	Range Cell Migration Correction
RPF	Radar Product Format
SAR	Synthetic Aperture Radar
SLC	Single-Look Complex
TE	Transverse Electric
TM	Transverse Magnetic
UH	Ultra High
VH	Vertical polarisation on transmit and Horizontal polarisation on receive
VV	Vertical polarisation on transmit and Vertical polarisation on receive
XWEAR	X-band Wideband eXperimental Airborne Radar

1 INTRODUCTION

1.1 Background

Defence Research and Development Canada (DRDC) has developed the X-band Wideband Experimental Airborne Radar (XWEAR) system which can operate in a number of advanced radar modes, including the Landspot and the Seaspot modes. In addition to conventional Landspot mode, where the nominal aircraft trajectory is a straight line, the XWEAR system also supports a circular SAR mode called VideoSAR (where a time series of images are formed as the aircraft flies in a nominally circular trajectory around a particular region-of-interest).

In operation, the XWEAR radar system generates a series of raw radar data pulses which are saved in files using a format described in Section 4.6 of Reference R-1. These raw data files can subsequently be processed to generate radar imagery. For this purpose DRDC has developed a phase-preserving Back-Projection processor which can be used to process raw XWEAR data from the Landspot and VideoSAR modes of operation. The processor can read the XWEAR raw data files as input and can generate a time-series of images where each image in the time-series is geometrically aligned with the other images to form a geo-registered image stack.

The images in the registered stack generated by the back-projection processor are saved in the form of a series of data files written using the Radar Product File (RPF) data format.

1.2 Purpose

The purpose of this document is to describe two MATLAB utility functions called the "Data Distribution Tools". The purpose of these two tools is to facilitate the reading of raw and processed XWEAR SAR data respectively, as outlined below:

- The first tool "XWEAR_RngProc.m" reads XWEAR Spotlight (Seaspot and Landspot) raw pulse data from raw XWEAR data files. This tool performs pulse compression and outputs the pulse compressed data together with parameter fields which can be used, as required, in any subsequent processing of the range-compressed pulses.

- The second tool "RPF_ProductRead.m", reads XWEAR Spotlight (Seaspot and Landspot) imagery which has been previously processed and written to RPF files in either SLC or detected form. This tool reads in the image pixel values together with associated parameter fields contained within the RPF formatted imagery files.

1.3 Structure of Document

Section 2 provides a list of reference documents.

Section 3 describes tool provided to read the raw XWEAR data file.

Section 4 describes the tool provided to read the RPF formatted XWEAR imagery files.

2 DOCUMENTS

2.1 Applicable Documents

None.

2.2 Reference Documents

R-1	ZS-IC-51-2741	"Interface Control Document for the Receiver / Exciter / Processor of the Airborne Radar Data Acquisition System [CDRL B02]", Issue/Revision 2/2. Sept 21, 2009, Yuejin Zhang, MDA.
R-2	AIRRADAR-SP-RPF	"Radar Product Format (RPF) Description", Issue/Revision 2/3. Last Update: June 29, 2012, Kurt Hagen, MDA.

3 XWEAR RAW DATA DISTRIBUTION TOOL

The tool is called “XWEAR_RngComp”. The MATLAB file contains the following header record which provides a quick outline of how the tool is used. This header record information is available at the MATLAB command line by typing:

> help XWEAR_RngComp

```
XWEAR_RngComp    Range Compression for XWEAR data

 [rc, info] = XWEAR_RngComp(  FILE, PATH, StartLine, NumLines, TmShift )

  the input parameter FILE must be supplied

  the remaining input are optional with default value used if needed

  FILE      : the Raw XWEAR file name (without the .00 extension)
  PATH      : absolute or relative path to directory containing raw data
  StartLine : the first line number to be processed (starts from 1)
  NumLines  : the number of raw range lines to be processed
  TmShift   : number of range samples to shift the TM channel

 [the starting line number is an overall line count across the complete
  acquisition which may correspond to multiple raw data files]

   Default Values:
     PATH      : ''   => current working directory
     StartLine : 1    => first line in input files
     NumLines  : 0    => used all lines in input files
     TmShift   : 0    => no shift applied to TM channel

Example of use: To compress 5000 lines of both the TE and TM channels
                starting from raw line number 200000.

  [rc, info] = XWEAR_RngComp( 'LSPT2UH060627133738FLT46_LEG14', ...
                              'C:\rawDataFiles\', 200000, 5000 );
```

3.1 Introduction

3.1.1 Target Coordinate System and Range-Compression

The XWEAR system makes use of a Cartesian (XYZ) coordinate system when acquiring raw radar data. This coordinate system is called the target coordinate system. An illustration of the Target Coordinate System is show in Figure 3-1. This figure show the radar located with y > 0 and illustrates a right-hand looking imaging scenario.

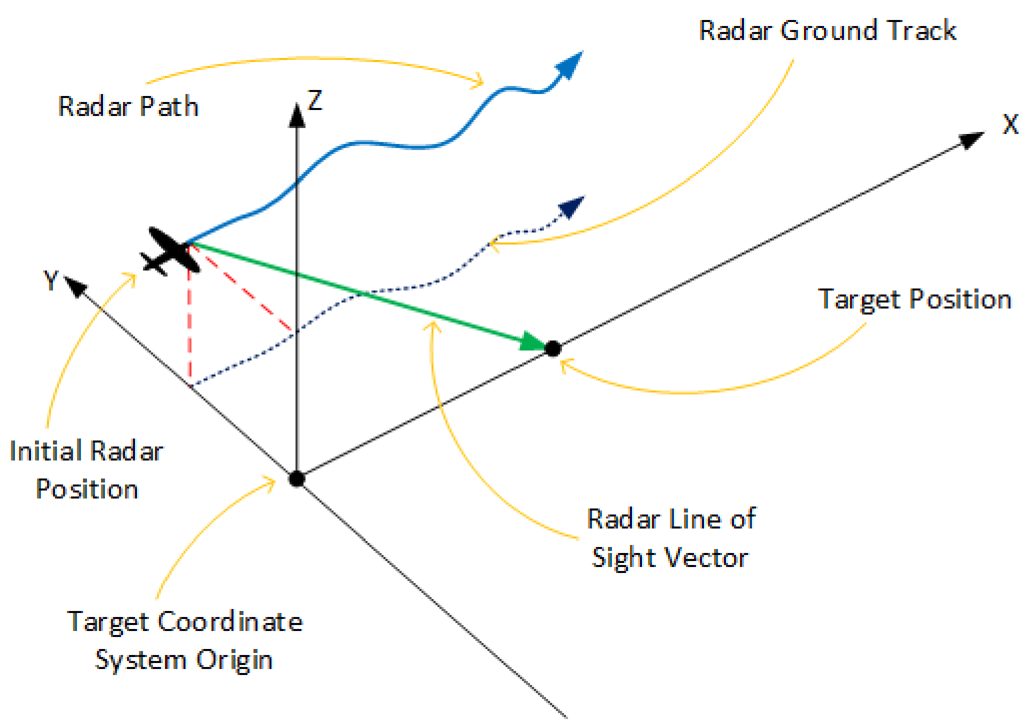

Figure 3-1 Target Coordinate System, with left-looking radar illustrated.

This system is oriented so that the 2D x-y plane, defined by z = 0, forms a locally horizontal plane which contains the specified imaged target location. The specified target location falls along the X axis (i.e. at a point where both y = z = 0). For Landspot mode, the target coordinate system remains stationary w.r.t. the earth-fixed and earth-centred coordinate system. However, for Seaspot mode, the origin of the target coordinate system moves in the local horizontal direction at a constant speed equal to the horizontal component of the initial estimated ship speed. In this way, in the ideal case where the initial estimated ship speed is accurate, then the ship position will remain approximately fixed w.r.t. the target coordinates system. In both Landspot and Seaspot modes, the X axis of the target coordinate points in the same direction as the aircraft ground-track at the start of the acquisition. Moreover, the aircraft position, at the mode startup, falls in the vertical plane defined by x = 0.

As raw pulses are collected, the radar's Antenna Phase Centre (APC) location is recorded along with each recorded pulse as a vector (XYZ) in the target coordinate system. For simplicity, the tool XWEAR_RngComp outputs these APC locations for each pulse *after shifting the* X *values by the initial target* X *coordinate value*. This means that the designated target position for both Landspot and Seaspot modes always falls at the origin (x = y = z = 0) in this X-shifted version of the target coordinate system, as illustrated in Figure 3-2.

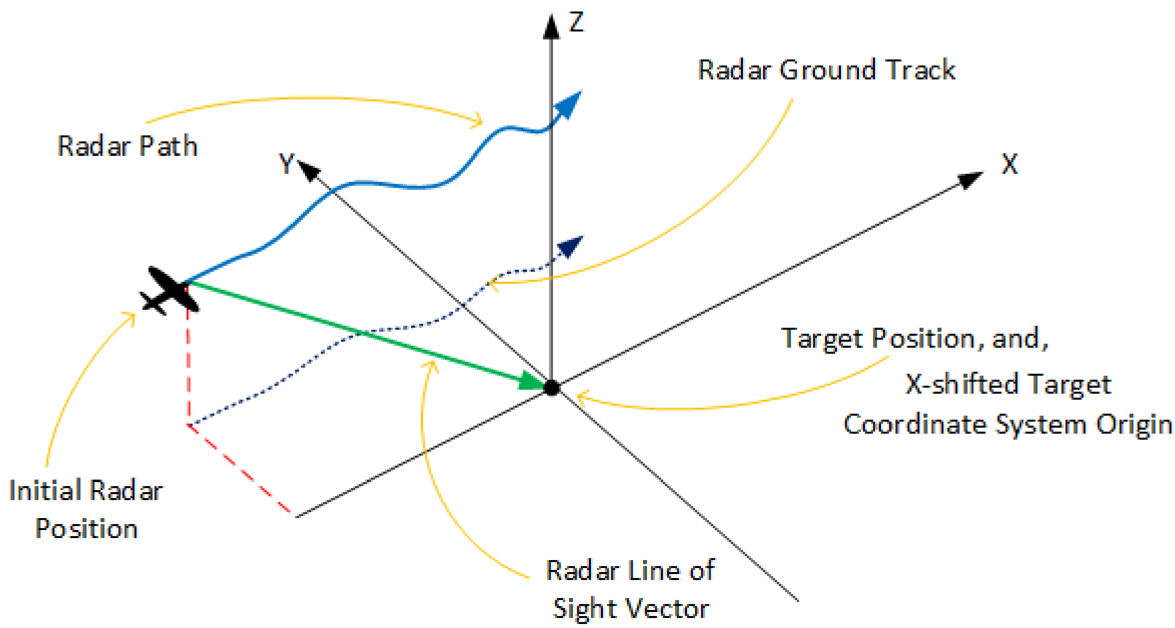

Figure 3-2 X-shifted Target Coordinate System (so that origin coincides with target location); diagram illustrates a left looking radar example.

The range compression performed by the tool uses the designated target position (i.e. uses the origin of the X-shifted target coordinates system) as the reference point for range-compression. This means that after range-compression: a notional isolated point target located at the designated target location (i.e. at the origin of the X-shifted target coordinates system) will, in the ideal case, where the radar APC location is measured without any error, result in a range compressed target signal which:

- falls at the centre sample of the range compressed swath, and,
- has constant azimuth value phase as a function of pulse number.

In other words, the XWEAR_RngComp tool, performs Range Cell Migration Correction (RCMC) using the measured radar APC location and applies a range shift to each processed as to align the centre of the compressed pulse with the designated target location. Furthermore, a corresponding phase correction (sometimes referred to as an azimuth de-ramp) is applied so as to reduce to signal phase, considered value as a function of azimuth, to a constant value for the notional target at the origin (under the assumption that there is no error in the APC position measurements).

A consequence of this RCMC and azimuth de-ramp processing is that a coarse-resolution 2D image can be readily formed from the range compressed data via a simple azimuth FFT operation. This is demonstrated in the example script provided with the current software delivery.

3.1.2 Antenna Configuration

When operating in the Landspot or Seaspot modes the XWEAR system can be configured to produce either non-polarimetric or polarimetric output data. The switch between these two configurations involves a major hardware change since the non-polarimetric and polarimetric options requires the use of a different transmit/receive antenna. In view of this, the radar data acquisitions performed within a single mission will all be in either the non-polarimetric or the polarimetric mode.

3.1.2.1 Non-Polarimetric Mode

In non-polarimetric mode the XWEAR system can be configured to generate either one channel or two-channels of raw pulse data. In two-channel configuration the two recorded channels are respectively called:

- Transverse Electric (TE) - first channel, and,
- Transverse Magnetic (TM) - second channel,

where the names TM and TE describe the principal modes of the electromagnetic propagation of the corresponding radio-waves within the antenna and feed horn.

For each transmitted pulse: two received pulses can be formed from the TE and TM propagation modes respectively.

- In single-channel operation, only the first of the above channels (TE) is recorded.
- In two-channel operation both the TE and TM data are recorded, however due to data rate constraints, the length of the recorded pulse in two-channel operation is half that used for single channel operation.

Typically, the pulse-repetition frequency (PRF) is held fixed for both Seaspot and for two-channel Landspot modes. In contrast, it is typically programmed to vary with time in single channel Landspot mode in order to minimize the total data volume whilst adequately sampling the azimuth bandwidth of the imaged scene. In this way, the variable PRF becomes a function of the imaging geometry and the radar speed.

The actual PRF value is determined by the radar from the following equation:

$$\text{PRF} = |\boldsymbol{v}| \sin \Theta \; / \; 0.1875 \qquad \text{(Hz)}$$

where Θ is the angle between the radar velocity vector, $\boldsymbol{v}$, and the radar-line-of-sight vector, $\boldsymbol{r}$.

3.1.2.2 Polarimetric Mode

In polarimetric modes the XWEAR system can be configured to generate either dual-polarization or quad-polarization data as follows:

- Horizontal transmit with dual receive [HH–HV], or,
- Vertical transmit with dual receive [VH–VV], or,
- Alternating transmit with dual receive [HH-HV & VH-VV].

In all cases, for each transmitted pulse, the two received polarizations are recorded in the raw data file in a similar manner to that use for the two-channel non-polarimetric case. Thus, the recorded pulse length in all three polarimetric modes is equal to the recorded pulse length in the two-channel non-polarimetric modes.

3.1.3 Range Shift between the Two Channels

In all modes where two-channels of data are recorded for each transmitted pulse, the XWEAR system generates raw data that has unwanted range-offset between the two recorded channels. Thus the second channel can be considered as containing an offset in range by a fixed range-shift relative to the first channel. The tool XWEAR_RngComp.m allows for this range-shift to be corrected during the range compression so that the corresponding range-compressed outputs are aligned in slant range.

If the range-offset is known, then its value can be input to the XWEAR_RngComp tool as the 5th input parameter. If its value is not known in advance, then the value can be estimated using another tool called "XWEAR_EstRangeOffset.m". This MATLAB tool contains the following header record which provides a quick outline of how the tool is used. This header record information is available at the MATLAB command line by typing:

```
> help XWEAR_EstRangeOffset
```

```
XWEAR_EstRangeOffset   Estimate Range Offset between TE and TM channels

 XWEAR_EstRangeOffset( FILE, PATH )

 Estimates the range offset of the TM01 channel relative to
 the TE11 channel.
   FILE is the two-channel raw file name (without filename extension).
   PATH is the input file path, either relative or absolute:
       '' means input file is in current working directory

 If only a subset of the complete set of input files needs to
 be processed, this can be controlled by using the optional parameter
 StartLINE and NumLINES.

    XWEAR_EstRangeOffset( FILE, PATH, StartLine, NumLines )

 The functions uses a default value of 32 for the number of input
 raw range lines to be skipped over.  A different value can be
 specified using the optional unput parameter LineSKIP.

    XWEAR_EstRangOffset( FILE, PATH, StartLine, NumLines, LineSKIP )

 EXAMPLES:
  Process 5 input raw files in working using default parameter:
    resu = XWEAR_EstRangeOffset( 'LSPT2UH060627133738FLT46_LEG14', '' )

  Process 50000 lines from 5 files in parent directory starting
  at line #10000 and using a range line skip factor of 100 :
    resu = XWEAR_EstRangeOffset( 'LSPT2UH060627133738FLT46_LEG14', ...
                                 '../', 10000, 50000, 100, 1)
```

When the tool XWEAR_EstRangeOffset is run, it returns the estimated range shift in units of range samples. In addition, the results of the run are also saved as a MATLAB save file located in the current working directory. The name of this save file is formed as the concatenation of:

- the input raw XWEAR data file name (excluding the .00 file extension), and,
- the string "_Rng_Info.mat".

Subsequently, the value of the estimated shift can then be recovered by loading this MATLAB save file (instead of re-running the estimation tool XWEAR_EstRangeOffset).

3.2 Inputs

The XWEAR_RngComp tool takes up to 5 inputs from the input argument list together with a larger number of inputs taken from a configuration parameters file called "XWEAR_ConfigParams.m".

3.2.1 Input Argument List

The input argument list accepts from 1 to 5 input arguments in the order listed below:

1. FILE : the Raw XWEAR file name (without the .00 extension)
2. PATH : absolute or relative path to directory containing raw data
3. StartLine : the first line number to be processed (starts from 1)
4. NumLines : the number of raw range lines to be processed
5. TmShift : number of range samples to shift the TM channel

The first argument is required whereas the subsequent four arguments are optional. If not supplied directly, the following default values are used by the tool in place of arguments 2 through 5 respectively:

2. PATH : current working directory,
3. StartLine : 1 => first range line in the file,
4. NumLines : 0 => all the available raw range lines in the data set
5. TmShift : 0 => no range shift correction is applied

3.2.2 Configuration Parameters File.

A collection of parameter values used by the tool are contained in the file "XWEAR_ConfigParams.m". Some of the parameter values listed in this file should be considered as having fixed values which should not be changed. However a number of the parameters which affect the behavior of the tool can be changed and these are briefly discussed below [all the other parameter values in the configuration file, not explicitly mentioned here, should not have their values adjusted].

```
% Approx maximum number of lines (in thousands) to be processed
nThousandLines = 10;
```

The above parameter controls the allocation of memory used to read the pulse data from the raw data file. For fastest processing, smaller values are recommended for this parameter. If large volumes of data are to be range compressed, then the function XWEAR_RngComp be called many times from within a loop with the startLine number being advanced on each pass through the loop. This is much more efficient from a memory perspective than attempting to process a very large number of range lines within a single call to XWEAR_RngComp.

```
% XWARE replica is either read from a file or generated using the
% nominal parameter values contained in the configuration parameters
'replicaSelection', 'genNominal', ... % 'readRepFile' or 'genNominal'
```

This parameter controls whether range compression is performed using a nominal replica function on one derived from a replica data file.

```
'pulseReplicaFileName', 'RFGG2SH120912183930FLT92_AIRBORNEChan1',
```

This parameter specifies which replica file should be used in the event that the 'replicaSelection' parameter is set to 'readRepFile'.

```
% The range collapse factor determines the range resolution of the
% processed data. A range collapse value of 1 means process to
% finest range resolution. A larger value for the range collapse
% correspond to a lower range resolution.
'collapseFactor',  1,   ...   % Range Collapse Factor: 1,2,4,8,16,32
```

A range collapse factor of N means that the output range compressed data is generated with range resolution and sample spacing of N times that of the finest resolution option (which is generated when N = 1).

```
'rangeSwath',  'narrow', ...  % 'wide', 'medium' or 'narrow'
... "wide" in the previous line gives the widest possible
...   image swath (but the range resolution is degraded towards the
...   range swath edges). The swath width is widest at range-collapse 1.
... "narrow" gives narrower swaths corresponding to the regions where the
...   range resolution is not degraded. However the swath width is
...   smallest at range-collapse 1 (much smaller than in the "+" case).
... "medium" gives a swath width which does not depend on the collapse
...   factor (some range resolution degradation will be present at the
...   swath edges when low collapse factors are used.  The swath widths
...   generated will fall mid-way between the "wide" and "narrow" cases
...   described above.
```

The 'rangeSwath' parameter allows for wider processed swath widths to be traded-off degraded range resolution towards the swath edges. The effect on the output swath width is most significant when the finest resolution data sets are processed to the finest resolution (i.e. when the data is acquired using UH range resolution and processed using rangeCollapse = 1). Figure 3-3 illustrates the resulting dependence of processed range-bandwidth on output swath width (where is should be noted that resolution is inversely proportional to processed range-bandwidth).

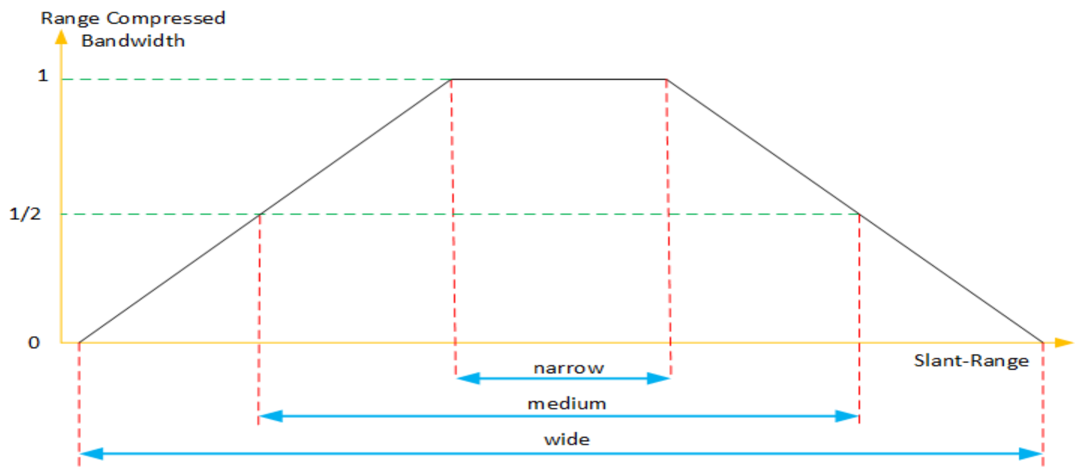

Figure 3-3 Output Swath Width and Processed Range-Bandwidth

For example, if we consider two-channel data collected at UH range resolution. The UH range replica length is 10000 real-valued range samples. The real-valued raw data line length for two-channel data is 16384 range samples and the real-valued sample spacing is 7.5 cm. Hence in this case, the three options for 'rangeSwath' are as follows:

'narrow': The range compressed output data has full resolution across the processed swath-with. The extent of the range throwaway after range compression is equal to the full replica length giving an output swath width of (16384-10000 = 6384 samples or) **478 meters**.

'medium': The range compressed output data has full resolution within the centre 478 meters. However the output swath width is (16384 samples, or) **1229 meters**, with the range-resolution linearly degrading to ½ of its finest value towards the near and far edges of the 1229 meter wide output swath.

'wide': The range compressed output data has full resolution in the centre 478 meters. However the output swath width is 16384+10000 samples, or **1979 meters**, with the range-resolution linearly degrading to zero towards the near and far edges of the 1979 meter wide output swath.

```
'elevGainCorrection', 'off', ... % select one of the following:
 %   'off',  'R4', 'R3', 'Ant', 'R4*Ant' or 'R3*Ant'
```

After range compression, an option exists to correct for the antenna elevation gain pattern and/or the range spreading loss. The variable 'elevGainCorection' controls whether elevation gain correction is applied and if so, whether it consists of range spreading loss (which can be applied as R^3 or R^4, or antenna pattern correction, or a combination of the two).

```
'elevGainPatSelection',  'genNominal', ... 'genNominal' or 'readFromFile'
```

If antenna elevation gain pattern correction is selected (i.e. 'elevGainCorrection' is set to one of 'Ant', 'R4*Ant' or 'R3*Ant') then the antenna elevation gain pattern to be used for correction is specified by the parameter 'elevGainPatSelection'. The two allowed values 'genNominal' or 'readFromFile' indicate the source of the gain pattern to be used.

```
   'nominalBeamWidthElev',  5.0, ... Task23 =>  3.276, ... % degrees
   'nominalBeamOffsetElev', 0.0, ... Task23 => -0.637, ... % degrees
   'nominalBeamAmpCutOff',  0.1, ... minimum gain pattern cut off
```

If the elevation gain pattern selection 'elevGainPatSelection' is set to 'genNominal' then the antenna elevation gain pattern correction is calculated as a perfect 'sinc' function, truncated by a minimum gain cut-off value, as specified by the three parameter values above.

```
'antElevGainFile', 'antennaPattern\antennaElevationPattern', ...
...  Note the antElevGainFile is only needed if one of:
...     "Ant", or 'R4*Ant' or 'R3*Ant' is selected for 'elevGainCorrection'
...     and if 'elevGainPat' is set to 'readFromFile'.
```

If the elevation gain pattern selection 'elevGainPatSelection' is set to 'readFromFile', the elevation gain pattern can be read in from a file and the input file is specified by the above parameter.

```
'refRange',        15000, ...    % reference range for gain spreading loss
```

If the elevation gain correction contains a range spreading loss component (i.e. either R^3 or R^4) then a reference range is used as part of the elevation gain correction. The reference range values is specified by the parameter 'refRange'.

```
'rollOffsetAng',    0, ...       % Roll Offset in Degrees (see below)
```

If the elevation gain correction contains the antenna elevation gain component (i.e. one of 'Ant', 'R4*Ant' or 'R3*Ant') then the calculation of the antenna elevation pointing angle involves the use of the parameter 'rollAngleOffset' which is an XWEAR configuration parameter set by the operator as part of the radar data acquisition. Note that for many data acquisitions, this parameter value is set to zero degrees.

```
'windowCoef',        0.54, ... % Raised Cosine weighing function parameter
...                            % [0-1; 1 means no window; 0.54 means Hamming]
```

The 'windowCoef' specifies the side-lobe suppression window function used during range-compression.

```
'invAmpScaling', 'yes',    ... % controls inverse scaling of pulse spectrum
```

The 'invAmpScaling' flag can be set to either 'yes' or 'no' and determines whether or not the spectrum of the range replica function is to be modified by scaling its amplitude such that the product of the echo spectrum and the replica spectrum is flattened (as a function of range-frequency).

3.3 Outputs

In the code line below, the primary outputs from a call to the XWEAR_RngComp function are called 'rc' and 'info'. These variables contain the range-compressed data and a structure of decoded parameter values respectively.

```
[rc, info] = XWEAR_RngComp(  FILE, PATH, StartLine, NumLines, TmShift )
```

3.3.1 Range Compressed Data

The first output parameter ('rc' in the example above) is a 2 or 3D array of range compressed data samples in single precision floating point. Dimensions of this array are as follows:

1. First dimension (rows): The size of the array in this dimension is the number of valid range compressed samples, *N*rcSamp,
2. Second dimension (columns): The size of the array this dimension is the number of range-compressed pulses, *N*azSamp,
3. Third dimension: corresponds to the number of channels in the raw data file.

Thus, for non-polarimetric, single-channel data, the range-compressed output is a 2D array of size [*N*rcSamp x *N*azSamp]. For all other cases, the output is a 3D array of size [*N*rcSamp x *N*azSamp x 2] where the two elements in the third dimension correspond to input channel numbers 1 and 2 respectively.

3.3.2 Information record

The second output parameter is a structure, called 'info' in the example above. This output structure contains the following fields:

- speedOfLight : scalar value used during range processing (m/s)
- inputFileName: text string giving name of input raw data file.
- firstProcLineNum: scalar integer giving index of first processed range line
- lastProcLineNum: scalar integer giving index of last processed range line
- procStartTime: text string giving time when XWEAR_RngComp run starts
- procEndTime: text string giving time when XWEAR_RngComp run ends

- pulseTimeSecs: vector (of length *N*azSamp) giving transmitted pulse time (sec)
- pri: vector (of length *N*azSamp) giving pulse repetition interval (sec)
- secSinceMidnight: vector (length *N*azSamp) giving time since midnight (sec)
- apcPos: 2D array (size NazSamp x 3) giving APC location in XYZ coords.
- apcVel: 2D array (size NazSamp x 3) giving APC velocity in XYZ coords.
- timeToFirstSamp: vector (length *N*azSamp) giving fast-time to first sample (sec)
- azimAngRawDeg: vector (length *N*azSamp) giving antenna azimuth angle (deg)
- numRngLinesProc: scalar giving the number of processed range lines (*N*azSamp)
- rgCompCentXyz: (3x1): range-compression centre point (always [0, 0, 0] meters)
- numRgSampOut: scalar giving number of output range samples (*N*rgSamp)
- rngBandWidth: Processed (focused) range-bandwidth (in units of Hz)
- numChannels: Number of channels in raw data file (size of 3rd dim of 'rc' array)
- radarMode: text string specifying either 'Landspot' or 'Seaspot'
- polarization: text string specifying polarization mode
- chanOne: array of size NazSamp x 2 [one of TE, TM, HH, HV, VH or VV]
- chanTwo: array of size NazSamp x2 [one of TE, TM, HH, HV, VH or VV]

The above output records are considered sufficient for many applications where range compressed data together with decoded parameter fields are required for subsequent signal processing operation such as azimuth compression.

3.3.3 Additional Outputs

For completeness and for historical reasons the function XWEAR_RngComp also outputs two additional parameters, as follows:

- header: Header Record (3^{rd} output parameter),
- mlp: Motion Line Parameters (4^{th} output parameter).

The header record is a structure containing a set of fields which provide the values in the raw data file header record structure as described in Table 4-36 of Ref R-1. For convenience, this table is reproduced within this document in Appendix A.

The motion line parameters, is a structure containing a set of fields which provided the pulse-by-pulse values extracted from the raw data file ancillary record structure as described in Table 4-38 of Ref R-1. For convenience, this table is reproduced within this document in Appendix B.

Note that the output structures 'header' and 'mlp' have been included primarily for completeness and historical reasons. Many of the values in these records have not been fully decoded. Thus, many of the fields remain in the original units, as used within the raw data structures (and as described within Table 4-36 and Table 4-38 of Ref R-1).

3.4 Example of Tool Usage

A MATLAB script has been provided as part of the delivery to illustrate the use of the "XWEAR_RngComp" tool. The script is located in the following directory and is called "ExampleScript": i.e.:

\procExamples\XWEAR_raw\ExampleScript

Before running this script, it should be edited so that the "pathName" and "fileName" (at lines # 8 and 9) refer to an XWEAR Landspot two-channel, or polarimetric, raw data set available for processing.

Assuming that the flat "skipRngOffsetMeasurement" (at line # 16) is set to 'false', then the tool first calls the function "XWEAR_EstRangeOffset" to estimate the shift between the two recorded data channels.

The tool then makes three consecutive calls to the function XWEAR_RngComp, each time processing a set of 500 contiguous range lines, as indicated in the corresponding argument lists. Then, in a fourth call to the function, the same overall set of 1500 range lines is processed in a single function call. The script then compares:

- the results of processing the three sets of 500 lines separately, with
- the results of processing one set of 1500 lines.

These two methods are demonstrated to provide identical results.

Finally, the script produced 4 plots illustrating the coarse-resolution imagery formed by taking an azimuth FFT of the range-compressed results and displays some of the field values from the information structure 'info'.

4 XWEAR IMAGERY DATA DISTRIBUTION TOOL

The tool is called “RPF_ProductRead”. The MATLAB file contains the following header record which provides a quick outline of how the tool is used. This header record information is available at the MATLAB command line by typing:

> help RPF_ProductRead

```
RPF_ProductRead.m
=================

Purpose:
--------
   The purpose of this function is to read in a specific landspot or
   Seaspot frame or a stripmap block.
   Note that STMP products must have 1 file per block for this tool.

Inputs:
-------
   fileName       - any file name in acquisition
   frameNum       - frame number for Landspot & Seaspot or
                    block number for Stripmap
   blkFileNames   - Optionally pass in the list of file names. This will
                    save time for STMP acquisitions.
Outputs:
--------
   annotStruct - a single annotation data structure
                 (specific frame if landspot / seaspot,
                  first block found if stripmap)
                 (also contains image data chunk header)
   latLongGrid - an array of latLongGrid structures
   imageData   - image data pixels [row x col] (optional)
```

4.1 Introduction

DRDC has developed a number of SAR processors which accept XWEAR raw data files as input and produce focused SAR imagery, written to disk in the form of a series of RPF data files. These RPF files can store imagery in SLC or detected form in either integer or floating point representation. The type of pixel stored in the RPF imagery files is determined by the SAR processor used to write the files.

The tool “RPF_ProductRead.m”, reads XWEAR Spotlight (Seaspot and Landspot) imagery from RPF files in either SLC or detected form. This tool reads in the image pixel values together with associated parameter fields contained within the RPF formatted imagery files.

The RPF is described in Ref R-2. That document describes the generic definitions in its Section 2 together with CP140 specific definitions in Section 3. The format used for XWEAR is very similar to that used for CP140 and for the purposes of this document the two are considered to be the same.

The tool can be called from the MATLAB command lines as follows:

```
[ano, llg, img] = RPF_ProductRead( fileName, frameNum )
```

4.1.1 Input Arguments

Two input arguments are required by the tool: the file name and the frame number. The file name can be used with or without a path prefix. The frame number is an integer starting from 1.

4.1.2 Output Arguments

The function returns up to three output arguments as follows:

1. ano (file annotation data),
2. llg (latitude/longitude grid data), and,
3. img (image pixel data).

4.1.2.1 Annotation Data

The annotation data output is a structure which, in turn, contains the following list of structure valued fields:

annotationDataHeader:	[1x1 struct]
fileIdParams:	[1x1 struct]
imgDisplayParams:	[1x1 struct]
acqInfoParams:	[1x1 struct]
seaspotTgtParams:	[1x1 struct]
landspotTgtParams:	[1x1 struct]
stripmapTgtParams:	[1x1 struct]
processingInParams:	[1x1 struct]
commonOutput:	[1x1 struct]
seaspotOutput:	[1x1 struct]
landspotOutput:	[1x1 struct]
stripmapOutput:	[1x1 struct]
latLongOutput:	[1x1 struct]
ownAircraftParams:	[1x1 struct]

processingIdParams:	[1x1 struct]
imageDataChunkHeader:	[1x1 struct]

The first 15 of these sub-structures match the 15 Annotation Data Chunks described in Sections 3.3.1 to 3.3.1.15 respectively of Ref R-2. The 16^{th} sub-structure matches the "Image Data Chunk Header" described in Section 2.2.1 of Ref R-2.

4.1.2.2 Latitude / Longitude Grid Data

The Latitude / Longitude Grid Data matches the Geo-Location Grid Lines specification defined in Section 3.3.1.16 of Ref R-2. In particular, the Latitude/Longitude Grid output parameter is a structure containing the following fields. Each field is a vector which has a length equal to the number of lines in the current image frame (in the example shown here the number of lines in the image is 1024).

lineNumber:	[1x1024 double]
beginGrSrRatio:	[1x1024 double]
midGrSrRatio:	[1x1024 double]
endGrSrRatio:	[1x1024 double]
beginLatitude:	[1x1024 double]
beginLongitude:	[1x1024 double]
midLatitude:	[1x1024 double]
midLongitude:	[1x1024 double]
endLatitude:	[1x1024 double]
endLongitude:	[1x1024 double]

There are 10 fields listed above and these 10 fields have names which match the 10 field descriptions provided in the Table in Section 3.3.1.16 of Ref R-2.

4.1.2.3 Image Pixel Data

The image pixel data is a 2D array of pixel values. The array can be either real valued or complex valued depending on whether the data was written to the RPF file as a detected image or as an SLC image respectively.

4.2 Example of Tool Usage

A MATLAB script has been provided as part of the delivery to illustrate the use of the "RPF_ProductRead" tool. The script is located in the following directory and is called "ExampleScript": i.e.:

\procExamples\XWEAR_imagery\ExampleScript

This script is provided together with a small set of 9 pre-processed Landspot RPF files to be used for this example. The example RPF files are located in the following directory:

\procExamples\XWEAR_imagery\RPF_Files\

The script loops over the 9 RPF files and reads the annotation and pixel value from each of the files in turn. The pixel values are used to form an image display using log scaling. Then a selection of the annotation values are displayed in the MATLAB command window.

A HEADER RECORD

The table re-produced below is Table 4-36 from Section 4.6.1.2 of R-1

Ref 1: Table 4-36 Header Record Format Description

Field #	Description	Byte Size	Data Type	Units	Format/Range
1.	Record synch code	4	ui	-	Fixed value 0xFE01FE01
2.	Header Record Size	4	ui	-	Size in bytes
3.	Ancillary Record Size	4	ui	-	Size in bytes
4.	Raw Echo Data Record Size	4	ui	-	Size in bytes
5.	Number of Data Records	4	ui	-	Number of Data Records in this Data File.
6.	Polarimetric mode Flag	4	ui	-	0 = non polarimetric mode; 1 = polarimetric mode, vertical polarization; 2 = polarimetric mode, horizontal polarization; 3 = polarimetric mode, alternate polarization;
7.	Format version number	8	c	-	ASCII format version number, 7chars + EOS (null character)
8.	Mission Identifier	40	c	-	39 chars (alphabets, integers, hyphens and underscores only) + EOS (null character)
9.	UTC Date of current acquisition	4	ui	day/ month/ year/ century	Date formatted in four fields. Field 1 (day), bits 0 to 4: valid range is 1 to 31. Field 2 (Month), bits 5 to 8: valid range is 1 to 12. Field 3 (Year), bits 9 to 15, valid range is 0 to 99. Field 4 (Century), bit 16: 0 = 19, 1 = 20. Note, 0 is the rightmost bit. Bit 17 to 31 are unused.

Field #	Description	Byte Size	Data Type	Units	Format/Range
10.	UTC Time of data acquisition	4	ui	Second/ minute/ hour	Time formatted in three fields. Field 1 (Seconds), bit 0 to 5: valid range is 0 to 59. Field 2 (Minutes), bit 6 to 11: valid range is 0 to 59. Field 3 (Hours), bit 12 to 16: valid range is 0 to 23. Note, 0 is the rightmost bit. Bits 17 to 31 are unused.
11.	Radar Mode	4	ui	-	Sea Spot = 1 Land Spot = 2 Strip Map = 3 RFG = 4 Search I = 5 Search II = 6 Search III = 7 Search IV = 8 Search V = 9 GMTI = 10 ABC = 11 WSS Strip Map = 12 BiStatic SAR = 13 Cyclops = 14 Video SAR = 15
12.	Number of Channels	4	ui	-	Single channel = 1 Two channel = 2

Field #	Description	Byte Size	Data Type	Units	Format/Range
13.	Resolution	4	ui	-	1 = Ultra High 2 = Super High 3 = High 4 = Medium (1.3 metre) 5 = not used 6 = 8.0 metres 7 = 0.3 metres 8 = 30 metres (See Table 3-1 for available options in each mode)
14.	Boresight misalignment value	4	fl	milliradians	-Pi/2 to Pi/2 in azimuth
15.	Boresight misalignment measurement UTC Date	4	ui	day/ month/ year/ century	Date formatted in four fields. Field 1 (day), bits 0 to 4: valid range is 1 to 31. Field 2 (Month), bits 5 to 8: valid range is 1 to 12. Field 3 (Year), bits 9 to 15, valid range is 0 to 99. Field 4 (Century), bit 16: 0 = 19, 1 = 20. Note, 0 is the rightmost bit. Bit 17 to 31 are unused.
16.	Boresight misalignment measurement UTC Time	4	ui	Second/ minute/ hour	Time formatted in three fields. Field 1 (Seconds), bit 0 to 5: valid range is 0 to 59. Field 2 (Minutes), bit 6 to 11: valid range is 0 to 59. Field 3 (Hours), bit 12 to 16: valid range is 0 to 23. Note, 0 is the rightmost bit. Bits 17 to 31 are unused.
17.	Sampling rate of data	4	fl	MHz	50 to 2000 MHz
18.	Reserved	4	ui		Pad bytes. Value = 0.
19.	Tracked Target data at start of acquisition (see **Error! Reference source not found.**)	1536	-	-	Repeated 32 times.
Fields 20 to 25 are constant MoComp Output Data					

Field #	Description	Byte Size	Data Type	Units	Format/Range
20.	Target Initialization Timestamp	4	ui	10 usec	Range: 0 .. 4294967295
21.	Target velocity in ECEF coordinates	12	fl	metre/sec	3 value vector
22.	Targeting frame to Earth Center Earth Fix frame Direction Cosine Matrix A position in targeting coordinates is converted to ECEF coordinates by multiplying by the targeting frame to ECEF Frame Direction Cosine Matrix and adding the current origin position.	72	dl	-	3 x 3 matrix
23.	Initial position vector of targeting frame origin in Earth Center Earth Fix coordinates (moves with target velocity). The origin position at any time is equal to the initial origin position plus the target velocity times the elapsed time since target initialization.	24	dl	metre	3 value vector
24.	Target Position Vector in targeting coordinate frame (constant because origin moves with target).	24	dl	-	3 value vector
25.	Initial APC position in targeting coordinate frame	24	dl	metre	3 value vector
26.	Radius of cylindical Earth for stripmap SAR	8	dl	metre	
Fields 27 to 33 are valid if Radar Mode = Sea Spot or Sea Spot Polarimetric					
27.	Target Specification Method	4	ui	-	One of the following specification method must be provided: 1 = Track target number 2 = Target geodetic latitude/longitude, speed, track angle, elevation

Field #	Description	Byte Size	Data Type	Units	Format/Range

28.	Tracked target number (method 1)	4	ui	-	If Target Specification Method = 1 then
					Tracked target number = 1 to 32.
					Else
					Track target number = 0.

29.	Target Geodetic Latitude (method 2)	8	dl	degree	Positive North
30.	Target Longitude (method 2)	8	dl	degree	Positive East
31.	Target Speed (method 2)	4	fl	metre/sec	-
32.	Target Track Heading (method 2)	4	fl	degree	Relative to true north. Positive clockwise.
33.	Target Elevation (method 2)	4	fl	metre	Range: 0 .. 5000
34.	Reserved	4	ui	-	Pad bytes. Value = 0.
Fields 34 to 37 are valid if Radar Mode = Land Spot or Land Spot Polarimetric					
35.	Target Geodetic Latitude	8	dl	degree	Positive North
36.	Target Longitude	8	dl	degree	Positive East
37.	Target Elevation	4	fl	metre	Range: -400 .. 5000
38.	Reserved	4	ui	-	Pad bytes. Value = 0.
Fields 38 to 47 are valid if Radar Mode = Strip Map or Strip Map Polarimetric					
39.	Target Specification Method	4	ui		One of the following methods must be provided: 1 = Slant Range/Look Direction 2 = Target geodetic plus initial flight direction 3 = Target geodetic plus track angle 4 = Target geodetic start and Target geodetic stop
40.	Slant Range (method 1)	4	fl	metre	Slant range to swath centre
41.	Look Direction (method 1)	4	ui	-	1 = Left, 2 = Right
42.	Reserved	4	ui	-	Pad bytes. Value = 0.
43.	Target Geodetic Latitude (methods 2-4)	8	double	degree	Positive North
44.	Target Longitude (methods 2-4)	8	double	degree	Positive East
45.	Target Elevation (methods 2-4)	4	fl	metre	Range: -400 .. 5000

Field #	Description	Byte Size	Data Type	Units	Format/Range
46.	Target Track Angle (method 3)	4	fl	degree	Relative to true north. Positive clockwise.
47.	End Target Geodetic Latitude (method 4)	8	dl	degree	Positive North
48.	End Target Longitude (method 4)	8	dl	degree	Positive East
Fields 48 to 53 are valid if Radar Mode = Search I, II, III, IV or V or Search I, II, II, IV or V Polarimetric					
49.	Sector Type	4	ui	-	1 = Full scan 2 = Gated sector scan 3 = Sector scan Mode I – Full or Gated scan Mode II – Full or Sector scan Mode III – Full or Sector scan Mode IV – Full or Gated scan
50.	Slant Range	4	fl	metre	Valid if Full scan selected (i.e., to get tilt)
51.	Sector Width	4	ui	-	0 = not used 1 = 20 degrees 2 = 40 degrees … 7 = 140 degrees valid if Sector scan or Gated sector are selected
52.	Reserved	4	ui	-	Pad bytes. Value = 0.
53.	TDS Geodetic Latitude	8	dl	degree	Positive North, valid if Sector scan or Gated sector are selected
54.	TDS Longitude	8	dl	degree	Positive East, valid if Sector scan or Gated sector are selected
Fields 54 to 61 are valid if Radar Mode = GMTI					
55.	Sector Width	4	ui	-	0 = not used 1 = 20 degrees 2 = 40 degrees … 7 = 140 degrees

Field #	Description	Byte Size	Data Type	Units	Format/Range
56.	Target Specification Method	4	ui		One of the following specification method must be provided: 1 = Target Geodetic Latitude/Longitude 2 = Target Range and Bearing 3 = Fixed Range and Fixed Azimuth Angle
57.	Target Geodetic Latitude (method 1)	8	dl	degree	Positive North
58.	Target Longitude (method 1)	8	dl	degree	Positive East
59.	Target Range (method 2, 3)	4	fl	metre	-
60.	Target Bearing (method 2)	4	fl	degree	Relative to true north. Positive clockwise.
61.	Target Elevation	4	fl	metre	Range: -400 .. 5000
62.	Fixed Azimuth Angle (method 3)	4	fl	degree	Relative to nose of aircraft. Positive clockwise.
Fields 62 to 65 are valid if Radar Mode = ABC					
63.	Sector Width	4	ui	-	0 = not used 1 = 20 degrees 2 = 40 degrees … 7 = 140 degrees
64.	Target Elevation	4	fl	metre	Range: -400 .. 5000
65.	Target Geodetic Latitude	8	dl	degree	Positive North
66.	Target Longitude	8	dl	degree	Positive East
67.	Header record checksum	4	ui	-	Exclusive OR of all previous four-byte words in the header record
68.	Reserved	12	ui	-	Pad bytes. Value = 0.
	TOTAL	2048	-	-	(divisible by 8)

B ANCILLARY DATA RECORD

The table re-produced below is Table 4-38 from Section 4.6.1.4 of R-1

Ref 1: Table 4-38 Ancillary Data Format Description

Field #	Description	Byte Size	Data Type	Units	Format/Range/Comment
1.	Record synch code	4	ui	-	Fixed value 0xAB55AB55
2.	Record index number	4	ui	-	Range: 0 .. 4294967295 Resets to zero at mode start
3.	Pulse Start Timestamp (ZRT)	4	ui	10 usec	Range: 0 .. 4294967295 Timestamp is taken at the start of the pulse.
4.	RF Attenuation	4	ui	dB	Range: 0 .. 62, increment by 2. Updated when set RF Attenuation command is received from the GUI. Maximum time uncertainty is around 0.1 second.
5.	Azimuth Encoder Data	4	ui	-	Bit0 – bit11: unsigned 12 bit azimuth encoder value, Range: 0 .. 4095, LSB = 4.88281E-04 Pi radians. Bit12: In Bulk Head flag, set to 1 when azimuth encoder value is in the range of 1200 – 2895, set to 0 otherwise. Bit 13: Data Overflow flag, set to 1 if the hardware register is overflow, set to 0 otherwise. Bit14 – bit31: set to 0, not used New valve read each PRI

Field #	Description	Byte Size	Data Type	Units	Format/Range/Comment
6.	Polarimetric Information	4	ui	-	Bit0 – bit15: unsigned 16 bit Polarimetric Switch Delay value Range: 0 .. 65535, LSB = 16 ns. Bit16 – Polarimetric Switch Mode control: set to 0 for manual, set to 1 for alternate. Bit17 – Polarimetric Switch Select (valid only if Bit16 is set to 0) : set to 0 for vertical, set to 1 for horizontal. Bit18 – Polarimetric Switch Status : 0 indicates vertical, 1 indicates horizontal. Bit19 – Bit31: not used
7.	EGI Data (see 4.5.1.5)	184	-	-	Updated at 1 Hz
8.	IMU Data (see 4.6.1.6)	24	-	-	Updated at 200 Hz
9.	Motion compensation output data (see 4.6.1.7 : or Appendix B1)	264	-	-	see B1 for update frequency details
10.	Ancillary data checksum	4	ui	-	Exclusive OR of all previous four-byte words in Ancillary Data
11.	cPCI Pulse Sequence Number	4	ui	-	Range: 0 .. 4294967295 Set to 0 at mode start
12.	Sampling Delay From Trigger	4	ui	ps	Range: 0 .. 4294967295
13.	First Sample Byte Offset in 32-bit Word	4	ui	-	Range: 0 .. 3
	TOTAL	512	-	-	(divisible by 8)

B1 MoComp Output Data

The table re-produced below is Table 4-47 from Section 4.6.1.7 of R-1

Ref 1: Table 4-47 MoComp Output Data

Field #	Description	Byte Size	Data Type	Units	Format/Range/Comment
1.	Timestamp of most recent reset of first slave navigator	4	ui	10 usec	0 .. 4294967295 LSB = 10 usec
2.	Timestamp of most recent reset of second slave navigator	4	ui	10 usec	0 .. 4294967295 LSB = 10 usec
3.	APC position vector at ZRT	72	dl	metre	3 x 3 values, corresponding to the master and 2 slave navigator solutions Updated at 200 Hz and linearly interpolated to each ZRT
4.	APC velocity vector at ZRT	36	fl	metre/sec	3 x 3 values, corresponding to the master and 2 slave navigator solutions Updated at 200 Hz and linearly interpolated to each ZRT
5.	Reserved	4	ui	-	Pad bytes. Value = 0.
6.	MoComp phase reference point position vector at ZRT	72	dl	metre	3 x 3 values, corresponding to the master and 2 slave navigator solutions Updated at 200 Hz and linearly interpolated to each ZRT
7.	MoComp PRI reference point speed at ZRT	12	fl	metre/sec	3 values, corresponding to the master and 2 slave navigator solutions Updated at 200 Hz and linearly interpolated to each ZRT
8.	Antenna platform roll	4	fl	radian	-PI .. PI Updated at 200 Hz and linearly interpolated to each ZRT
9.	Antenna platform pitch	4	fl	radian	-PI .. PI Updated at 200 Hz and linearly interpolated to each ZRT

Field #	Description	Byte Size	Data Type	Units	Format/Range/Comment
10.	Antenna platform heading	4	fl	radian	-PI .. PI Updated at 200 Hz and linearly interpolated to each ZRT
11.	Commanded azimuth angle of antenna	2	usi	degree	0 .. 4095, maps to 0 .. 360 degrees LSB = 0.088 degrees with respect to aircraft heading Updated at 200 Hz, but the command is only sent to the DSC at 10 Hz.
12.	Commanded tilt angle of antenna	2	si	degree	1 .. 26, maps to –15 .. 10 degrees Updated at 200 Hz, but the command is only sent to the DSC at 10 Hz.
13.	Reserved	4	ui	-	Pad bytes. Value = 0.
14.	Pulse Repetition Interval (PRI) at ZRT timestamp	4	ui	nanosec	LSB = 16 nanosec Updated per PRI
15.	Range delay at ZRT timestamp	4	ui	nanosec	0 .. MAX (~2000000) LSB = 4/4096 nanosec Updated per PRI
16.	Computed azimuth angle to ABC target	4	fl	radian	Only for ABC mode Azimuth with respect to aircraft heading Updated at 2 Hz
17.	ABC azimuth error standard deviation	4	fl	radian	Only for ABC mode Updated at 2 Hz
18.	ABC position error standard deviation	4	fl	metre	Only for ABC mode Updated at 2 Hz
19.	Horizontal range to ABC target	4	fl	metre	Only for ABC mode Updated at 2 Hz
20.	Antenna azimuth misalignment estimate (antenna azimuth encoder minus MoComp azimuth)	4	fl	radian	Only for ABC mode Updated at 2 Hz

Field #	Description	Byte Size	Data Type	Units	Format/Range/Comment
21.	Antenna azimuth misalignment estimate error standard deviation	4	fl	radian	Only for ABC mode Updated at 2 Hz
22.	ABC data update flag	4	fl	-	Only for ABC mode, 1 : updated, 2 : not updated
23.	Reserved	4	ui	-	Pad bytes. Value = 0.
24.	TOTAL	264		-	(divisible by 8)