EMISAR data description

(as of January 1995)

Storage medium

Data are stored on 8 mm Exabyte tapes (8200 = low density).

Storage format

Data are stored in tar format with record length 10240 bytes.

Contents

Each tape holds:

- a read_me file
- source code of a utility program written in C-language (util.c)
- an executable of the utility program compiled for DOS PCs (util.exe)
- the polarimetric image in covariance matrix format
- the polarimetric image in scattering matrix format

Read_me file

The read_me file is an ASCII file with information on the mapping geometry, the image size etc. An example is enclosed in Appendix A.

util.c program

util.c is an ASCII file with the program source code. The program can be compiled with C and C++ compilers. It is menu driven, and once a SAR image is transferred to disk using the tar command, the program can:

- pick out a subimage
- perform type conversion including byte swap (DOS to UNIX or UNIX to DOS)
- detect the image (power, amplitude, phase)
- lowpass filter and resample
- perform a radiometric scaling and transformation

Appendix B illustrates the main menu and the sub-menus.

Scattering matrix format

The complex imagery includes four files (HH, HV, VH, and VV) of one-look, slant range, scattering matrix data. HV means vertical transmit polarisation and horizontal receive polarisation. Data are sampled at a 1.5 ∞ 1.5 m pixel spacing (slant range ∞ azimuth), but focused to a nominal resolution of 2 ∞ 2 m in order to suppress sidelobes. Data are motion compensated and calibrated.

The calibration includes a channel imbalance correction (phase and amplitude) and an absolute radiometric calibration. This implies that the radar brightness β° of a homogeneous area equals 4π times the spatial average of the pixel intensity (I^2+Q^2). The backscatter coefficient σ° is obtained as β° multiplied by sine to the local incidence angle (taking the topography into account). The radar cross section of a point target is 4π times the total energy of the target as found with the integral method. Cross-talk elimination is normally not performed as the EMISAR sensor provides a cross-talk ratio better than -25 dB.

Data are stored as range lines with the imaginary part of a pixel, Q, following the real part, I. The two byte "short float" format used (four byte IEEE float format with truncated mantissa) is supported by the util.c type conversion.

Covariance matrix format

The covariance matrix is defined as

$$\mathbf{C} = \begin{bmatrix} c_{hhhh} & c_{hhhv} & c_{hhvv} \\ c_{hvhh} & c_{hvhv} & c_{hvvv} \\ c_{vvhh} & c_{vvhv} & c_{vvvv} \end{bmatrix} = \left\langle \mathbf{S} \cdot \left(\mathbf{S}^*\right)^T \right\rangle = \left\langle \begin{bmatrix} S_{hh} \\ S_{hv} \\ S_{vv} \end{bmatrix} \cdot \begin{bmatrix} S_{hh}^* & S_{hv}^* & S_{vv}^* \end{bmatrix} \right\rangle = \begin{bmatrix} \langle S_{hh}S_{hh}^* \rangle & \langle S_{hh}S_{hv}^* \rangle & \langle S_{hh}S_{vv}^* \rangle \\ \langle S_{hv}S_{hh}^* \rangle & \langle S_{hv}S_{hv}^* \rangle & \langle S_{hv}S_{vv}^* \rangle \\ \langle S_{vv}S_{hh}^* \rangle & \langle S_{vv}S_{hv}^* \rangle & \langle S_{vv}S_{vv}^* \rangle \end{bmatrix}$$

where <x> is the expectation value of the stochastic quantity x, and x* is the complex conjugate of x. **S** is the scattering matrix, and $\mathbf{S}^T$ is the transposed matrix. The scattering matrix is written as a column vector with only three elements as the two cross-polarised channels, $\mathbf{S}_{hv}$ and $\mathbf{S}_{vh}$, are identical for all natural scatterers (reciprocity). The covariance matrix is easily seen to have symmetry properties: the three elements below the principal diagonal are the complex conjugate of the three elements above the diagonal.

When calculating the covariance matrix in practice, the two cross-polarised channels are averaged coherently, i.e. on a pixel by pixel basis the complex numbers are added and divided by two. Thereby the signal-to-noise ratio is improved. Further, the expectation value is replaced by some spatial average over a small area around each pixel, i.e. upon a pixel by pixel multiplication of one image by the complex conjugate of the another image the product image is low-pass filtered. Finally, due to the symmetry properties only six of the nine images are computed.

The covariance matrix imagery is first processed like the scattering matrix imagery, but subsequently it is subject to a post-processing consisting of the following sequence of operations:

- the two cross-polarised scattering matrix channels are coherently averaged
- the six product images are generated
- using a lowpass filter the six product images are spatially averaged and resampled at a 5 ∞ 5 m pixel spacing in ground grid.
- the radiometric calibration of the six lowpass filtered ground range images is changed from a β° calibration to a σ° calibration. Each pixel is multiplied by $4\pi \cdot \sin\theta$, where θ is the local incidence angle.

The filter impulse response has a fixed length in the slant range domain implying that the number of equivalent looks (the speckle noise reduction) is range independent, while on the other hand the ground range resolution is coarser in near range than in far range. In order to ensure that a subsequent high quality resampling can by applied to the covariance matrix data, aliasing has been suppressed by using an effective filter bandwidth somewhat smaller than the output sampling frequency. The penalty is a slightly blurred appearance of the imagery.

The calibration implies that the backscatter coefficients σ°_{hh}, σ°_{hv}, and σ°_{vv} are obtained as the spatial average of the pixels in the hhhh, hvhv and vvvv images, respectively. The radar cross section of a point target is the sum of the pixel values over the target extent multiplied by 25 m^2.

To be exact, the terms ground range and σ° should be replaced by pseudo ground range and pseudo σ°, respectively, because a flat earth with no topography is assumed in the post processing.

The covariance matrix data are stored as range lines (pixels in one line have the same azimuth position) in a 4 byte floating point format (byte swapped for direct PC usage) with each of the six channels in a separate file.

Appendix A

Read_me file example.

```
-------------
General info:
-------------

  EMISAR data      : pm027_m0955_siggefora

  Acquired         : July 5, 1995 at 10.12 UTC

  Frequency        : 5.3 GHz

  Altitude (WGS84) : 12498 m

  Look direction   : left

  Heading          : -155 Deg.


-------------------------------------
Scattering matrix data (slant range):
-------------------------------------

  File names:
    pm027_m0955_siggefora_lhh.pp
    pm027_m0955_siggefora_lhv.pp
    pm027_m0955_siggefora_lvh.pp
    pm027_m0955_siggefora_lvv.pp

  Data type:
    Complex 16 bit floats

  Size of images:
    Samples per line      : 6409  (range)
    Lines per file  : 8623  (azimuth)

  Pixel spacing:
    Range           : 1.499 m
    Azimuth         : 1.500 m

  Pulse bandwidth    : 100 MHz

  Processing bandwidth:
    Range           : 100 % (hamming weighted)
    Azimuth         : 100 % (hamming weighted)

  Slant range offset      : 15050 m (to the first sample in the file)

  Incidence angle (platform assumed 12388 m above a flat earth):
    Near range            : 33.9 Deg
    Mid  range            : 51.0 Deg
    Far  range            : 59.6 Deg


-------------------------------------
Covariance matrix data (ground range):
-------------------------------------

  File names (diagonal elements):
    pm027_m0955_siggefora_lhhhh.co
    pm027_m0955_siggefora_lvvvv.co
    pm027_m0955_siggefora_lhvhv.co
```

```
  Data type:
    32 bit floats, byte swapped for direct PC usage (1 2 3 4 -> 4 3 2 1)

  File names (off-diagonal elements):
    pm027_m0955_siggefora_lhhhv.co
    pm027_m0955_siggefora_lhhvv.co
    pm027_m0955_siggefora_lhvvv.co

  Data type:
    Complex 32 bit floats, byte swapped for direct PC usage (1 2 3 4 -> 4 3 2 1)

  Size of images:
    Samples per line      : 2554  (range)
    Lines per file  : 2586  (azimuth)

  Post-processing:
    The covariance matrix has been extracted from the scattering matrix data.
    For instance the data in the file pm027_m0955_siggefora_lhhhv.co have been
    calculated by the following sequence of operations:

      1) The data in pm027_m0955_siggefora_lvh.pp are added coherently to the
data
         in pm027_m0955_siggefora_lhv.pp and divided by two, pixel by pixel.

      2) The complex conjugate of the results are multiplied by the data in
         pm027_m0955_siggefora_lhh.pp, pixel by pixel.

      3) The resulting image is lowpass filtered, resampled at a 5 m by
         5 m pixel spacing in ground grid and radiometric corrected to
         Sigma0. For the ground range projection the platform is assumed
         12388 m above a flat earth.

    Note that the covariance matrix has been optimised for analysis purposes,
    and not for visualisation.


----------------
Utility program:
----------------

  The source code of a menu driven C-program, util.c, is enclosed. This
  program offers type conversion, byte swapping (DOS -> UNIX, UNIX -> DOS),
  subwindow extraction, detection and averaging. The program can be compiled
  by a standard C compiler or a C++ compiler, but be aware that small changes
  might be necessary due to machine differences.

  Version number : 1.02


------------------------------
Executable of utility program:
------------------------------

  An executable of util.c for PC usage is enclosed. This file is denoted
  util.exe.
```

Appendix B

util.c menus

```
       ---------- Main menu ----------

 (1)  Input file name            :
 (2)  Input data type            : complex 16 bit float
 (3)  Input parameter type       : AMPLITUDE
 (4)  Number of samples per line : 1024
 (5)  Number of lines            : 1024
 (6)  Input image storing format : UNIX

 (7)  Output file name           :
 (8)  Output data type           : complex 16 bit float
 (9)  Output image storing format: UNIX

 (10) Input scale factor         : 1.000000e+00
 (11) Windowing                  : OFF
 (12) Detection                  : OFF
 (13) Averaging                  : OFF
 (14) Transform to pixels        : OFF
 (15) Go
 (0)  Exit

Choose (1) to (14) for changing, (15) for execute or (0) for exit:


       ---------- Window menu ----------

 (1)  Windowing                        : ON
 (2)  Number of used samples per line : 1024
 (3)  Number of used lines            : 1024
 (4)  Sample offset                   : 0
 (5)  Line offset                     : 0
 (0)  Exit

Choose (1) to (5) for changing or (0) for exit:
```

```
       ---------- Detection menu ----------

 (1)  Detection             : ON
 (2)  Output parameter type : AMPLITUDE
 (0)  Exit

Choose (1) to (2) for changing or (0) for exit:


       ---------- Output parameter type menu ----------

 (1)  AMPLITUDE
 (2)  POWER
 (3)  PHASE (rad)
 (4)  PHASE (deg)

Choose (1) to (4) for setting data type:
```

```
       ---------- Average menu ----------

 (1)  Averaging          : ON
 (2)  Sample scale factor: 1.000
 (3)  Line scale factor  : 1.000
 (4)  Filter type        : WEIGHTED SINC
 (0)  Exit

Choose (1) to (4) for changing or (0) for exit:


       ---------- Filter type menu ----------

 (1)  Weighted sinc
 (2)  Raised cosine
 (0)  Exit

Choose (1) to (2) for changing og (0) for exit:
```

```
       ---------- Pixel transform menu ----------

 (1)  Transform to pixels : ON
 (2)  log10
 (3)  power

choose (2) to (3) for setting transformation type:


       ---------- Log transform menu ----------

 (1) Maximum value in dB : 0.000
 (2) Dynamic range in dB : 36.000
 (0) Exit

Choose (1) to (2) for changing or (0) for exit:


       ---------- Power transform menu ----------

 (1) Maximum value in dB : 0.000
 (2) Power               : 0.800
 (3) Fixpoint            : 16384.000
 (0) Exit

Choose (1) to (3) for changing or (0) for exit:
```