**Who is GAMMA**

GAMMA Remote Sensing Research and Consulting AG is a Swiss corporation founded in January 1995 by Charles Werner and Urs Wegmüller. It is located in Gümligen near Bern, Switzerland. GAMMA’s main activities include participation in Earth Observation related research programs, services and consulting in the field of microwave remote sensing and license sales for its SAR and interferometry software packages.

**Services**

GAMMA conducts SAR and interferometric processing for customers. In addition, it provides end to end support for the selection of appropriate data, the SAR and interferometric processing and analysis, the generation of interferograms, coherence maps, height maps, and surface displacement maps (subsidence, seismic displacement, landslides, glacier motion, etc.), hazard maps, the geocoding of interferometric products, and the development and application of landuse, forestry and agricultural algorithms.

**Available Stand-Alone Software**

- **GAMMA Modular SAR Processor (MSP)**
- **GAMMA Interferometric SAR Processor (ISP)**
- **GAMMA Differential Interferometry and Geocoding Software (DIFF&GEO)**
- **GAMMA Land Application Tool (LAT)**
- **GAMMA Geocoding and Image Registration Software (GEO)**
- **GAMMA Interferometric Point Target Analysis (IPTA)**

**Information**

For further information on products and services, to ask about license agreement conditions, or to request an offer, please contact us at the addresses given below.

Additional information may also be found at our WWW site (http://www.gamma-rs.ch).

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**ERS-1/2 Tandem, Bern (Switzerland): Shaded relief.**

Processing with GAMMA MSP, ISP, and DIFF&GEO. ERS raw data courtesy of ESA.
**System Overview**

The **GAMMA Modular SAR Processor (MSP)**, Interferometric SAR Processor (ISP), Differential SAR Interferometry and Geocoding Software (DIFF&GEO), Land Application Tools (LAT), and Interferometric Point Target Analysis (IPTA) are modular software packages useful to process synthetic aperture radar (SAR) images. SAR geocoding and image registration is also available in a separate module (GEO). The software is written in ANSI C language, chosen for its portability and efficiency in the processing of large data sets. The well documented structured code and the stepwise processing approach permits users to experiment with new algorithms and applications. Data of both spaceborne and airborne sensors including ERS-1/2, JERS-1, SIR-C, SEASAT, RADARSAT, ENVISAT ASAR, and the single-pass Dornier DOSAR interferometer have been successfully processed interferometrically. User-friendly display tools and full documentation in HTML language complement the software. Both binary and source code licenses are provided. Up-to-date algorithms were implemented to achieve accurate processing of the data while permitting timely processing of large data sets on a workstation computer or a PC operated under LINUX or NT operating system. The software is being updated to new sensors and processing techniques.

**GAMMA Modular SAR Processor (MSP)**

The **GAMMA Modular SAR Processor (MSP)** is a flexible, accurate range-Doppler SAR processor. It allows the generation of complex and real valued SAR images from raw data of the current spaceborne and airborne sensors. The processing includes radiometric calibration and is phase preserving for interferometric processing. Processing related parameters and data characteristics are saved as text files with system parameters referenced using simple keywords. The main modules of the MSP are pre-processing, range compression with optional azimuth pre-filtering, autofocus, azimuth compression, and multi-look post processing. The processed images are radiometrically normalized for the antenna pattern, along track gain variations of the radar, length of the azimuth and range reference functions, and slant range. Multi-look images are produced by time-domain averaging of the single look complex image samples. Special features to optimize the processing of data of the current spaceborne sensors are autofocus (all SAR), radio interference filtering (for JERS), Doppler ambiguity estimation, missing line detection (ERS-1/2), and secondary range migration (JERS, RADARSAT). An advanced motion compensation module is also available for processing of airborne SAR data.

**GAMMA Land Application Tools (LAT)**

The **GAMMA Land Application Tools (LAT)** are a collection of programs designed to support the data processing in the context of using SAR and SAR interferometry for land applications. The LAT include special programs for spatial and multi-temporal filtering, parameter estimation (adaptive coherence estimator, texture, temporal variability), and data visualization (RGB composites, HSI composites). There are programs to select test areas, and to extract the corresponding signatures (mean, standard deviation, histogram). Furthermore, the LAT supports simple classification schemes.

**GAMMA Interferometric Point Target Analysis (IPTA)**

The **GAMMA Interferometric Point Target Analysis (IPTA)** is a collection of tools to exploit the temporal and spatial characteristics of interferometric signatures collected from point targets to accurately map surface deformation histories, terrain heights, and relative atmospheric path delays. The analysis can be summarized as an iterative improvement of the model parameters to achieve an optimal match to the observed interferometric phases. The analysis is done for a selected list of points which correspond to point target candidates, which dramatically improves efficiency and storage requirements. The advantage of using point targets is that these do not exhibit geometric decorrelation such as distributed targets, permitting a more complete use of the data as even pairs with very long baselines can be interpreted, resulting in improved accuracies and temporal coverage. An important element of the IPTA is the analysis across the data stack, respectively in the time dimension. The IPTA is fully compatible with the other GAMMA software - identical phase models are used and programs to convert between the raster and vector data formats are included. ERS and JERS data stacks were processed with IPTA.

**Input data**

- SLCs, height map, lab

**Point list**

- (pixel, pmsk)

**SLC point data**

- (pixel, pmsk, plos, phase)

**Differential interferogram point data**

- (oh, x, y, x, y, x, y, pmsk)

**Interferometric point analysis**

- (oh, deff, sigma, drw, res, pmsk)

**Model refinement**

- (hgt, def, sigma, atm, res-atm, pmsk)

**Result**

- (heights, deformation maps and histories, quality information)

**Regression of interferometric phase differences between pair of point targets with respect to baseline and time, as used to derive relative height corrections and deformation rates.**

**GAMMA4 Interferometric Point Target Analysis (IPTA) processing flow chart. The model parameters are iteratively improved.**

**RADARSAT ("fine mode"), Bar Harbor, Maine. GAMMA MSP supports processing of all RADARSAT strip map modes. SAR raw data with courtesy of Radarsat International, RSI, Canada.**

**JERS-1, Mount Fuji (Japan): Multi-look intensity image. SAR processing with GAMMA MSP. SAR raw data courtesy of NASA.**
**GAMMA SAR AND INTERFEROMETRY SOFTWARE**

Subsidence map of the urban area of Bologna from ERS differential interferometry. One color cycle corresponds to a subsidence velocity of 1 cm/year starting from the stable base of the Appennini (in the south). Data processing with **GAMMA MSP**, **ISP**, and **DIFF&GEO**. ERS raw data courtesy of ESA.

**Landuse map for a part of Switzerland derived with ERS SAR interferometry. Data processing with **GAMMA MSP**, **ISP**, **DIFF&GEO**, and **LAT**. ERS raw data courtesy of ESA.**

**GAMMA Differential Interferometry and Geocoding Software (DIFF&GEO)**

The **GAMMA** Differential Interferometry and Geocoding Software (**DIFF&GEO**) is a collection of programs designed to support the differential interferometric processing as well as geocoding between range-Doppler coordinates and map projections. The reason for inclusion of these quite different processes into one software module is that geocoding capability is required for 2-pass differential interferometry.

**Geocoding:** Geocoding is the coordinate transformation between the coordinates of an imaging system, in this case range-Doppler coordinates of the SAR, and orthonormal map coordinates. Geocoding is necessary to combine information retrieved by the imaging system (e.g. the SAR image and products derived from it) with information in map coordinates (e.g. a digital elevation model, a landuse inventory, geocoded information from optical remote sensing, etc.). Geocoding together with image co-registration is also available as a stand-alone GEO module.

**Differential Interferometry:** The interferometric phase is sensitive to both surface topography and coherent displacement in between the acquisitions of an image pair. The basic idea of differential interferometric processing is to separate the two effects, allowing, in particular, to retrieve a differential displacement map. This goal is achieved by subtracting the topography related phase. The topography related phase can either be calculated from a conventional DEM (2-pass differential interferometry) or from an independent interferometric pair without phase component from differential displacement (3- and 4-pass differential interferometry). Various approaches are supported by the **DIFF&GEO** leading to a high flexibility with respect to data (DEM, SAR) availability and the feasibility of phase unwrapping.

**GAMMA Interferometric SAR Processor (ISP)**

The interferometric processor gives end to end support for generation of interferometric products starting with complex SAR data as the SLC products provided by the Processing and Archiving Facilities (PAFs) or as processed by the **GAMMA MSP**. The different modules include baseline estimation from orbit data, precision registration of interferometric image pairs, interferogram generation (including common spectral band filtering), coherence estimation, removal of flat Earth phase trend, adaptive filtering of interferograms, phase unwrapping using branch cut and minimum cost flow (MCF) algorithms, precision estimation of interferometric baselines from ground control points, derivation of topographic height, and image rectification and interpolation of interferometric height and slope maps. The display of the final and intermediate products is supported with display programs and programs to generate easily portable images in SUN rasterfile and BMP formats. Processing related parameters and data characteristics are saved as text files that can be displayed using open-source or commercial plotting packages. The main processing sequence is complemented by quality control and display programs.

**DOSAR, near Solothurn (Switzerland):** interferometric height map. SAR processing, motion compensation, and interferometric processing with **GAMMA ISP**. SAR data courtesy of Dornier GmbH and RSL Univ. Zürich.

**SIR-C, Amazon (Columbia):** Interferometric height map generated from SIR-C (L-Band, vv polarization) data for a tropical forest test-site. Interferometric processing with **GAMMA ISP**. SIR-C SLC data courtesy of JPL/NASA.

**ERS-1, Flevoland (The Netherlands):** RGB composite figure of the interferometric coherence of the September 19 / October 4 (red), October 4 / October 19 (green), and October 19 / November 9 (blue) 1991 pairs. Interferometric processing with **GAMMA ISP**. ERS SLC data courtesy of ESA.

**SIR-C, Yverdon (Switzerland):** landuse characterization by color composite of SIR-C (C-Band, vv pol.) interferometric coherence (red), backscatter intensity (green), and backscatter change (blue). Processing with **GAMMA ISP**. SIR-C SLC data courtesy of JPL/NASA.
**GAMMA SAR and Interferometry Software**

**GAMMA Modular SAR Processor (MSP): Flow Chart**

- **Data carrier with raw data and leaderfile**
- **Preprocessing and quality control**
  - Raw data and leaderfile transcription
  - Extraction of parameters from leaderfile
  - Processor parameters definition
  - Range spectrum estimation
  - Missing line detection and correction
  - Doppler ambiguity resolution
  - Doppler centroid estimation
  - Radio Frequency Interference (RFI) filtering
  - Time dependent processing parameters for the processing of long strips
- **Raw data** (fixed)
- **Sensor parameter file**
- **Antenna diagram**
- **Processing parameter file**
- **Quality control data & plots**
- **Display tools**
- **Single look complex (SLC) SAR data**
- **Display tools**
- **Multi-look intensity SAR data**

**Range Doppler processing sequence**
- Range compression
  - Receiver gain variation compensation
  - Azimuth presum (for quick-look generation)
- Autofocus (iterative application possible)
- Azimuth compression
  - Secondary range migration
  - Relative calibration (incl. antenna diagram)

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**GAMMA Interferometric SAR Processor (ISP): Flow Chart**

- **Data carrier with slc data and leaderfile or SLC data processed by MSP**
- **Preprocessing, quality control and image co-registration**
- **Interferogram generation**
  - Common spectral band filtering in range and azimuth
  - Optional baseline estimation from fringe rate and/or registration offsets
  - Coherence estimation
- **Phase unwrapping and height map generation**
  - Optional adaptive filtering of interferogram
  - Phase unwrapping by Minimum Cost Flow (MCF) or branch-cut algorithm
  - Refined baseline modeling using height control points
  - Computation of heights and true ground-ranges
- **Transformation of heights and other products to orthonormal coordinates**
- **Complex interferogram**
- **Registered intensities**
- **Coherence map**
- **Unwrapped phases**
- **Heights in SAR geometry**
- **Topographic height and other products in orthonormal geometry**

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**GAMMA DIFF&GEO and GEO Software: Geocoding Flow Chart**

- **DEM, dem_par**
- **DEM segment** (user defined resolution)
- **Initial geocoding lookup table, Simulated SAR intensity image**
- **DEM products**: Local incidence angle, True pixel size, Layover-shadow map
- **DEM segment**
- **DEM to MAP lookup table**
- **Initial geocoding lookup table**
- **SAR to MAP lookup table**
- **SAR coordinates**: Intensity, Coherence, Derived products, InSAR products, Differential products, Transformed products from MAP coordinates
- **MAP to SAR lookup table**
- **MAP coordinates**: DEM, DEM Products, Landuse inventory, GIS Layers, Transformed products from SAR coordinates