NORTHROP GRUMMAN
Electronic Systems

AERONAUTICAL SYSTEMS CENTER

Complex SAR Compression

Fran Cirillo

SAIC

Imagery Compression Symposium II

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UAV BATTLELAB

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Overview

- SAIC has developed a patent-pending compression algorithm, capable of compressing Complex Synthetic Aperture Radar (SAR) data, near lossless, at compression ratios exceeding 20 to 1
- Preserves the phase information
  - Also preserves the magnitude information
- Developed for data transmission, archival, storage
- Applicable for Video Phase History (VPH) and Single Look Complex (SLC) datasets
- Experiments performed with multiple datasets, from multiple platforms, including ERS, ASARS-2, and Navy P-3
- Additional experiments performed with acoustic data

Complex SAR Compression (CSC) Contract

- SAIC has a contract with the Air Force (ASC/RA and the UAV Battlelab) and Northrop Grumman Corporation to integrate the SAIC developed complex SAR compression algorithm into the Common Imagery Processor (CIP)

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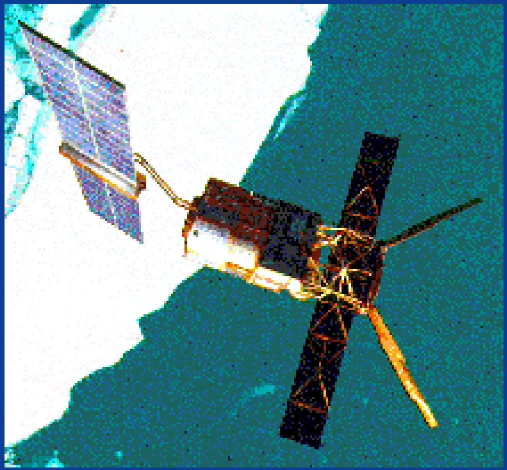
IR&D Project

- SAIC sponsored an Internal Research and Development (IR&D) project to investigate and solve the complex SAR compression problem
  - Achieved goal of a 20 to 1 compression ratio
  - Preserved the phase information
    - Also preserved the magnitude information
  - Successfully compressed VPH and SLC radar data
  - Developed metrics to verify phase data integrity
- Patent applied for with the US Patent Office on October 11, 2002

Complex SAR Datasets



European Space Agency (ESA)
Remote Sensing Satellites (ERS-1/2)

Advanced Synthetic Aperture Radar
System (ASARS-2)

Navy P-3 Orion Aircraft
(Polarimetric Data)

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Compression Process

Preprocessor → Transform → Quantizer → Encoder → Postprocessor

- These basic steps are required to compress most data types
- Most compression techniques take advantage of local data correlation to achieve their high compression ratios
  - Electro-Optical (EO) data is highly correlated so compression techniques capitalize on this quality
- Because complex data is highly uncorrelated, additional processing is required to efficiently compress the data

Compression Process

- Analysis of the experimental results determined that the Preprocessor and the Quantizer hold the key to complex data compression

- The Quantizer is the most important step in any compression process, because this is where most "unrecoverable" losses will occur with the data

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Preprocessor

- Accepts complex imagery as input
  - Converts the data from magnitude and phase to In-phase (I) and Quadrature (Q)
- Identifies the base radar data type
- Uses the statistics of the data to down convert to an 8 bit (0 – 255) format for later conversion to Bitmap (BMP) format
  - Several tests are performed on the data to determine the upper and lower limits
- Converts the I and Q data to BMP (8-bit) format

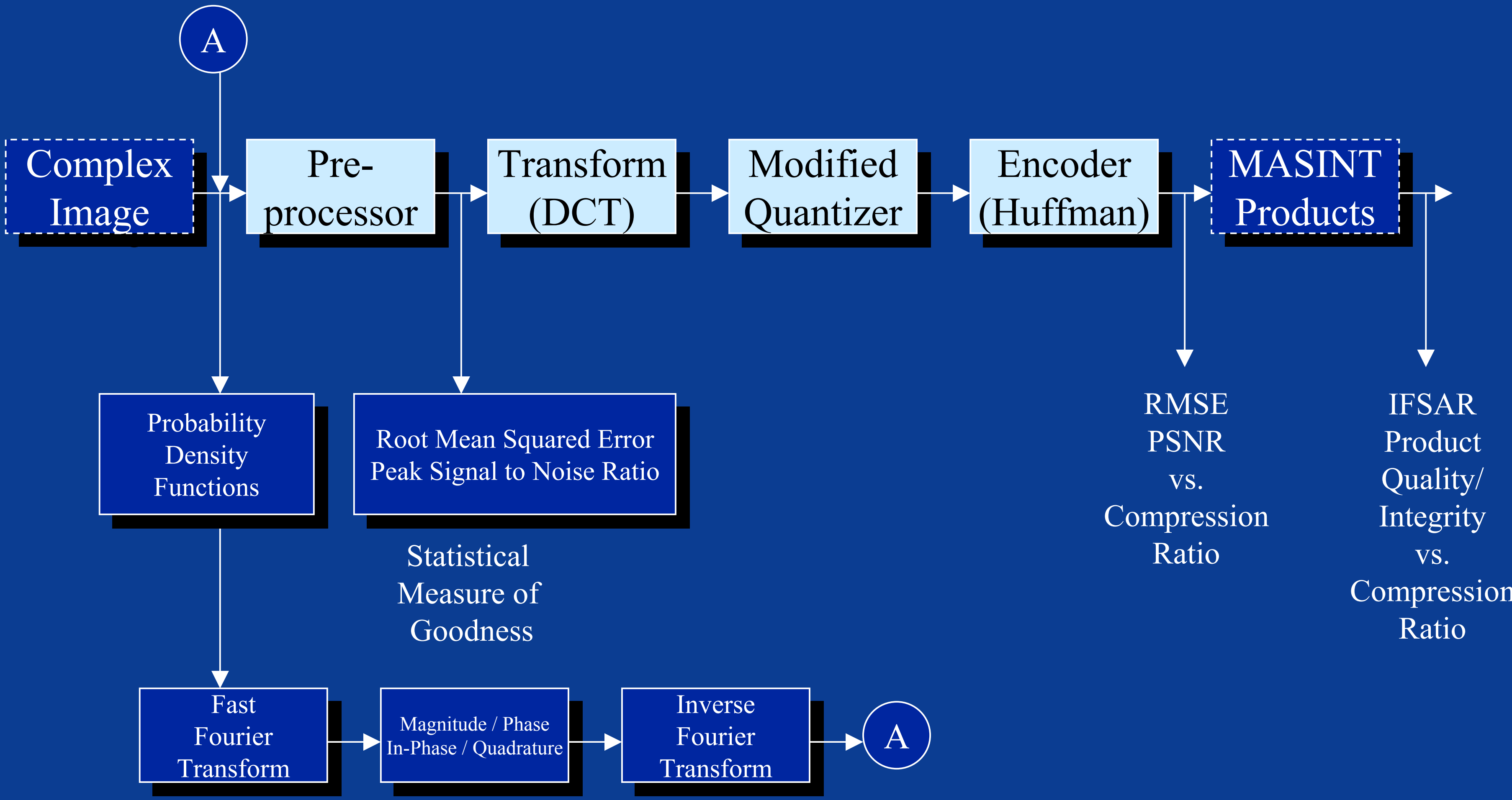
Preprocessor

- Calculates statistics for the original and converted data
  - Root Mean Square Error (RMSE)
  - Peak Signal to Noise Ratio (PSNR)
  - Mean Phase Error (MPE)
  - Mean Absolute Magnitude (MAM)
- Selects the appropriate quantization table from the knowledge base

Quantizer

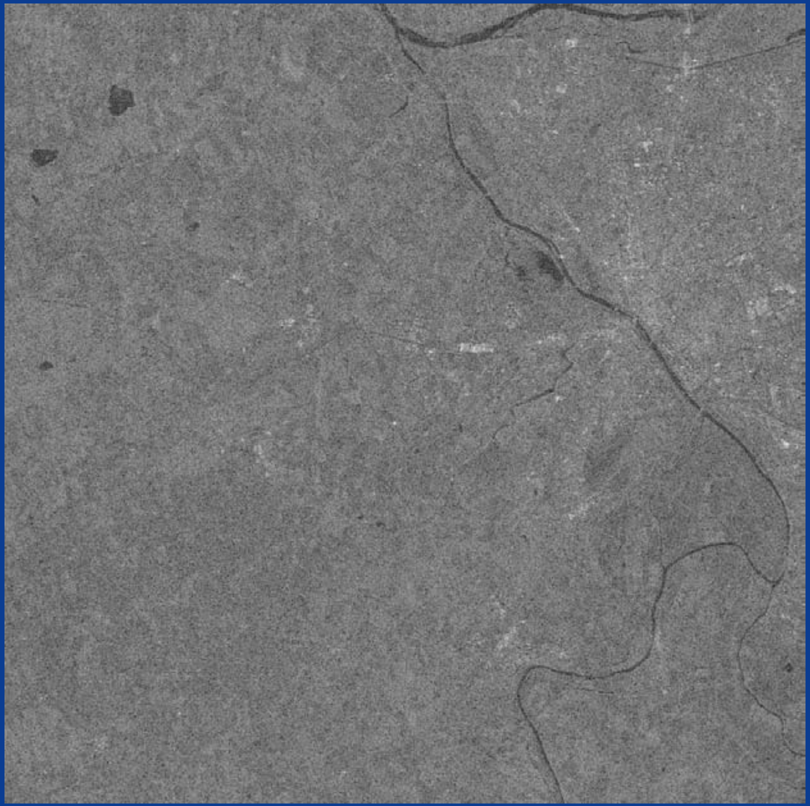
- JPEG Quantization tables were developed primarily for EO imagery
- Our team developed quantization tables that are based on the statistics of the complex radar data
- Tables are stored in a knowledge base and are chosen based on the identified base radar type
- A default quantization table is available for use as required

Compression Process

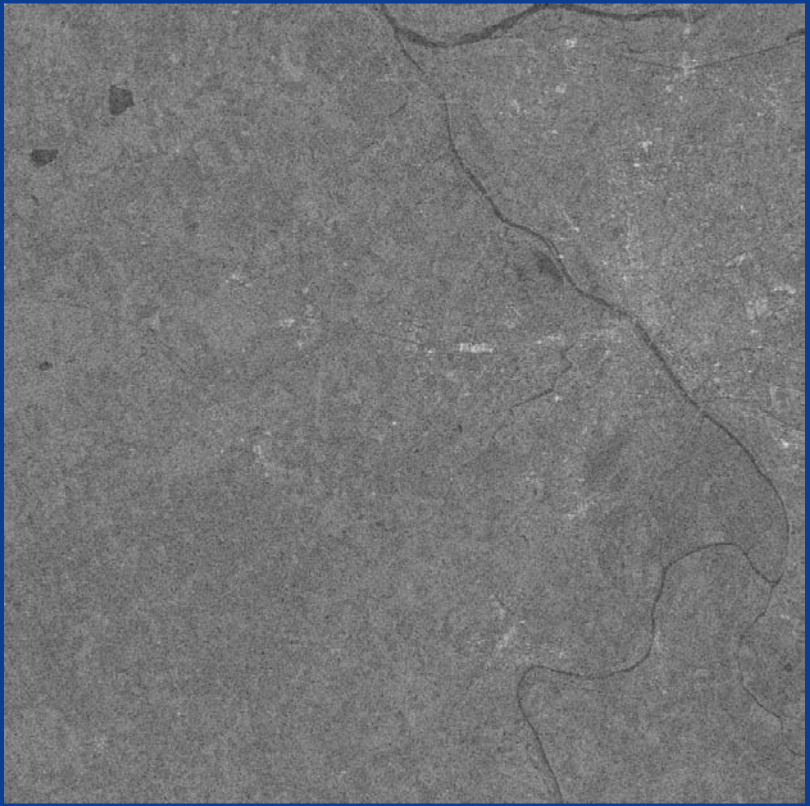


Compression Results (Magnitude Image)

Original



21:1 Compression



Brittany, France Original and 21:1 Compressed Images

Polarimetric Data

- L and P-Band Polarimetric data from the P-3 aircraft
- Real-time compression of VPH and SLC data for transmission and archival
  - IFSAR and Polarimetric applications

HH

HV

VV

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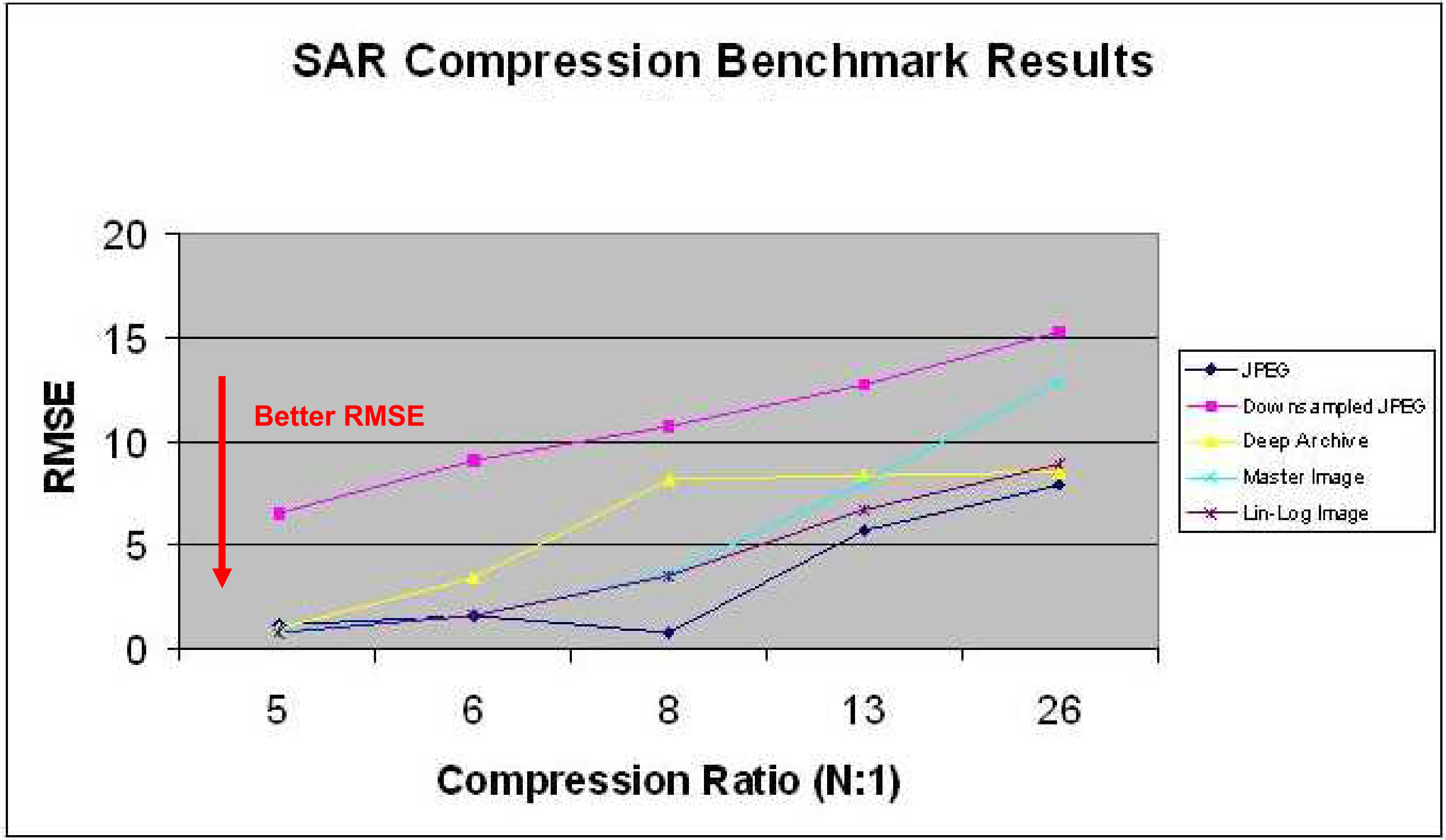
EO Related Metrics

- The following metrics were used to analyze the data:
  - Root Mean Square Error (RMSE)
  - Peak Signal to Noise (PSNR)
  - Mean Absolute Magnitude (MAM)
  - Data Overlay Plots
- Metrics were applied to the Magnitude and Phase information, as well as the In-phase and Quadrature (I&Q) data

Root Mean Square Error Comparisons



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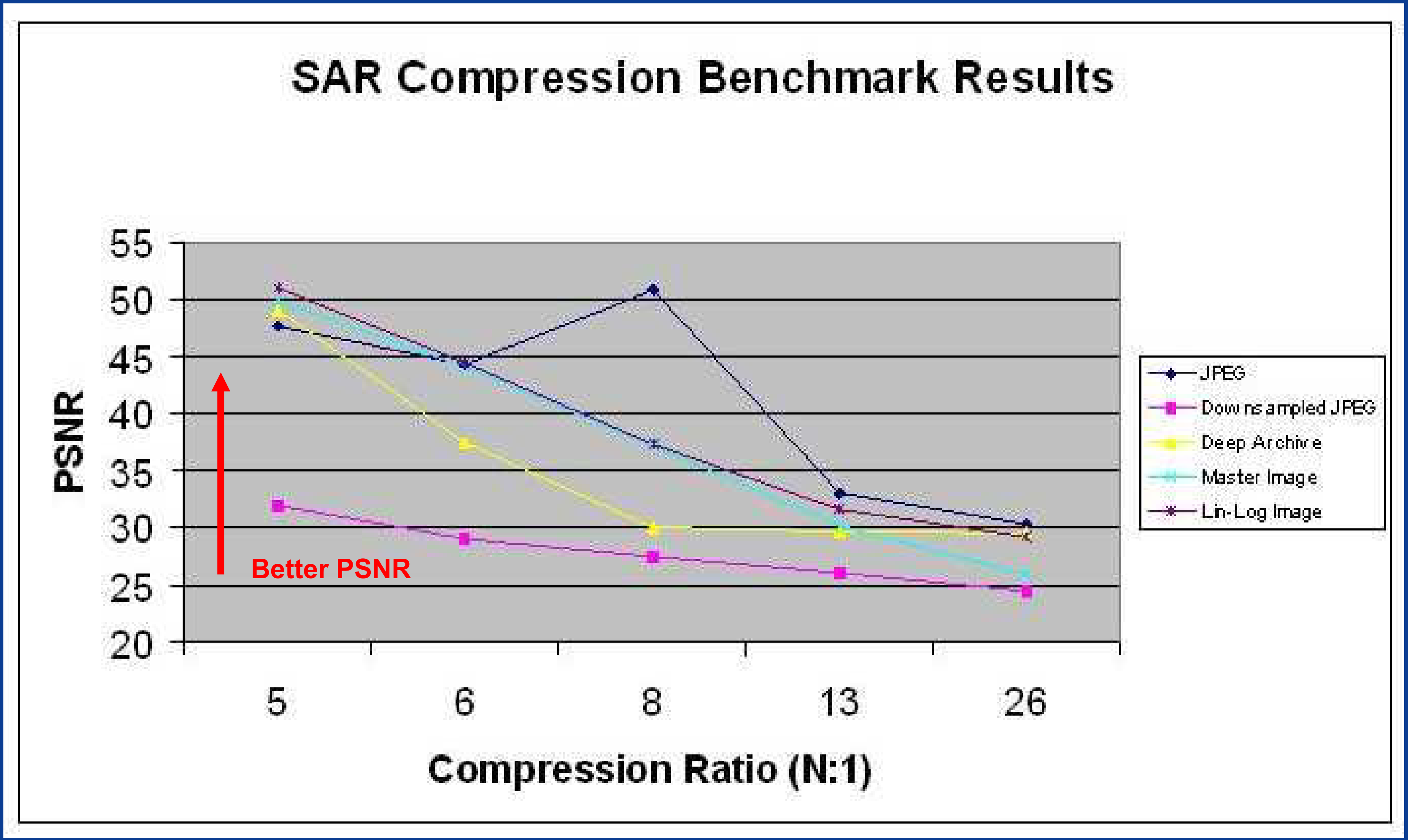
Peak Signal to Noise Ratio Comparisons



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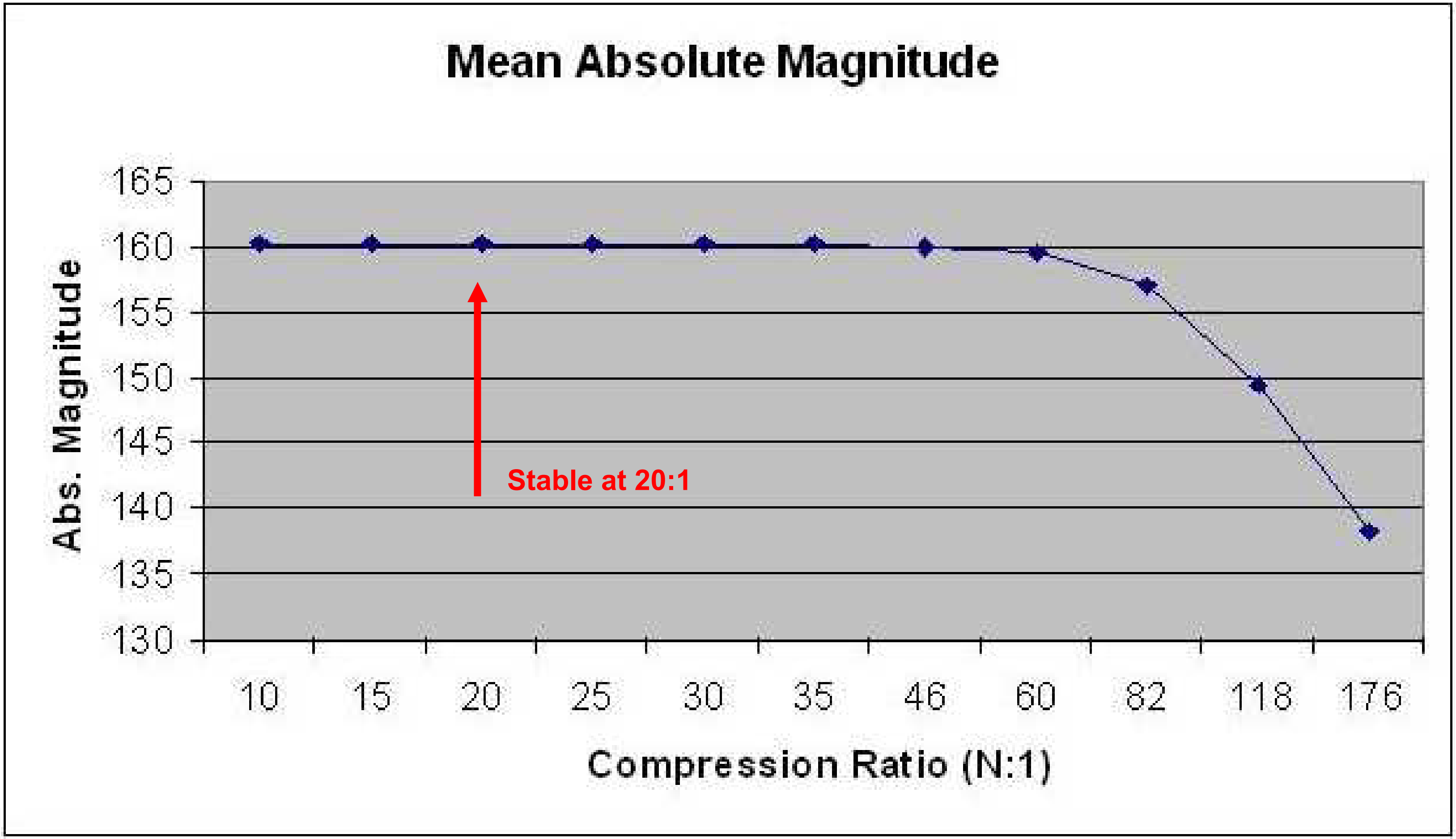
Mean Absolute Magnitude

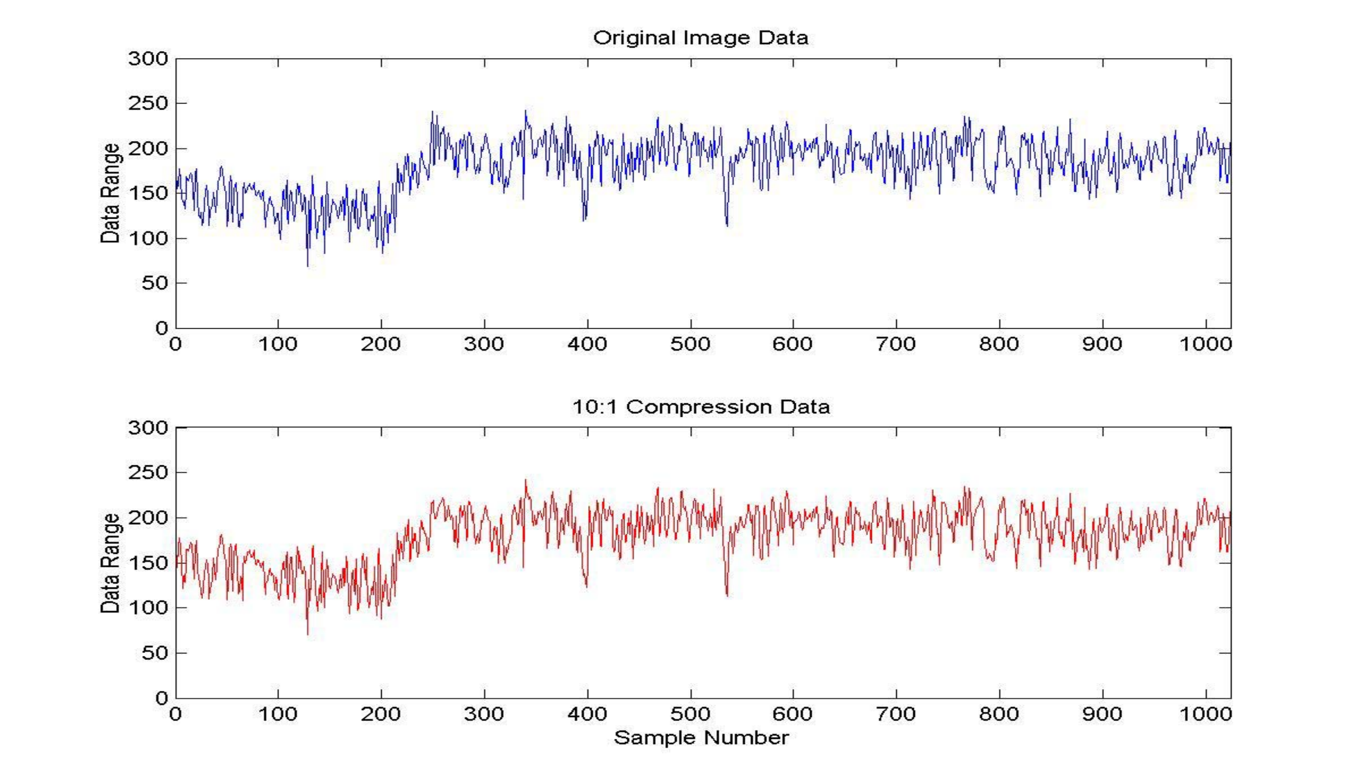


Data File Comparisons

Slices selected from the original and decompressed datasets

Original

Compressed/ Decompressed



The following plots are overlaid for comparison where deviations are most evident by the blue (original data)

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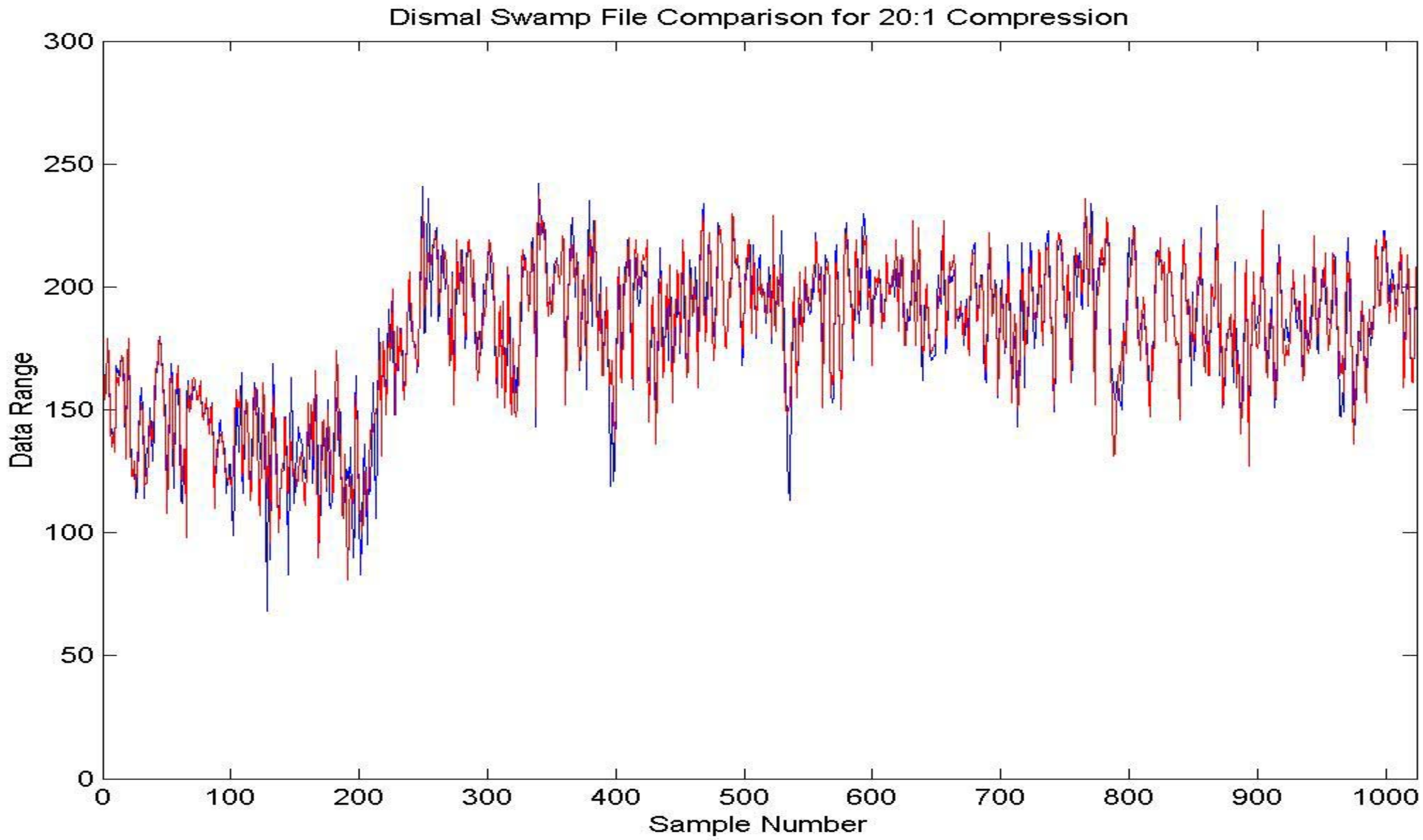
Magnitude Comparison

20 to 1 Compression



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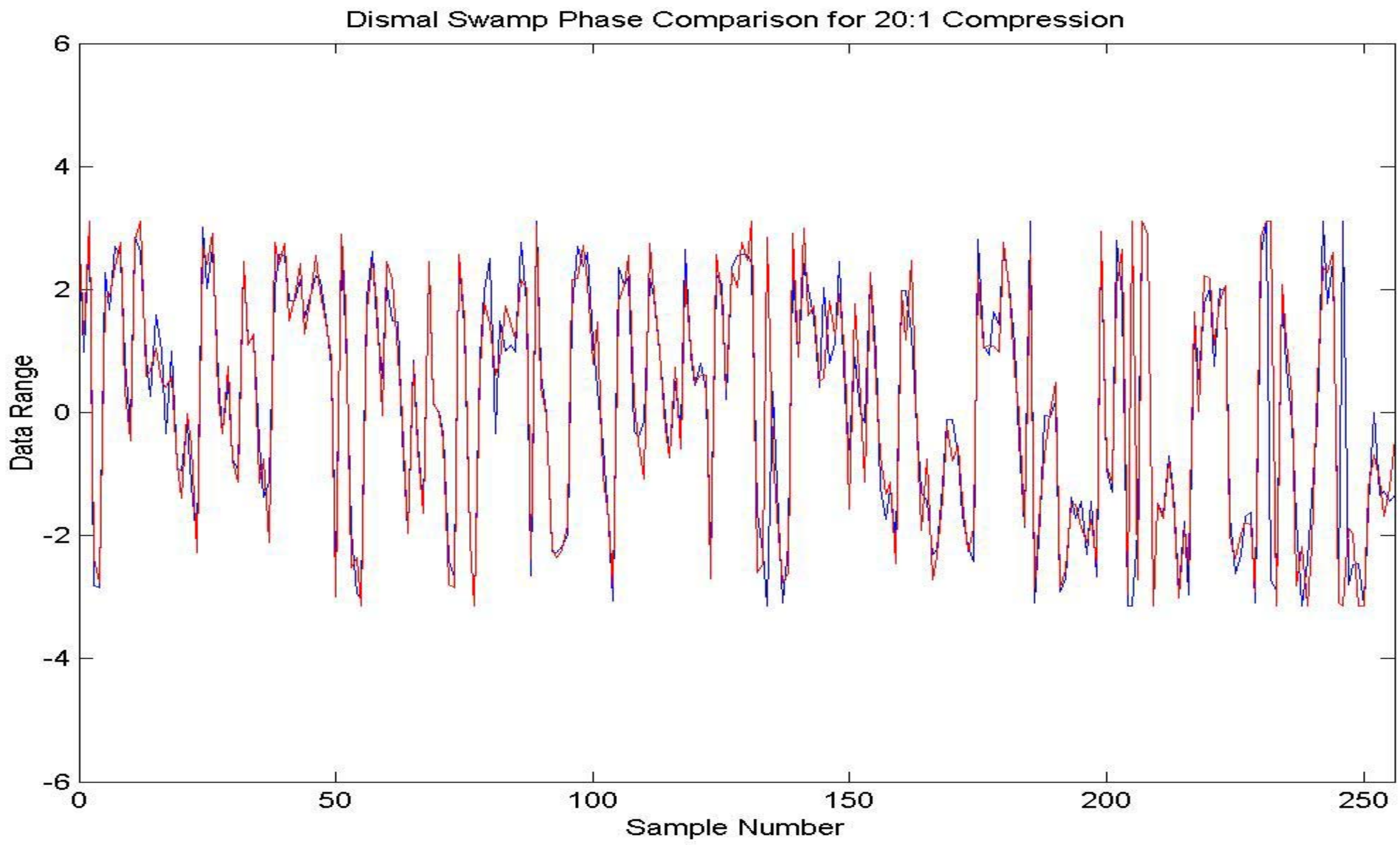
Raw Phase Comparison

20 to 1 Compression



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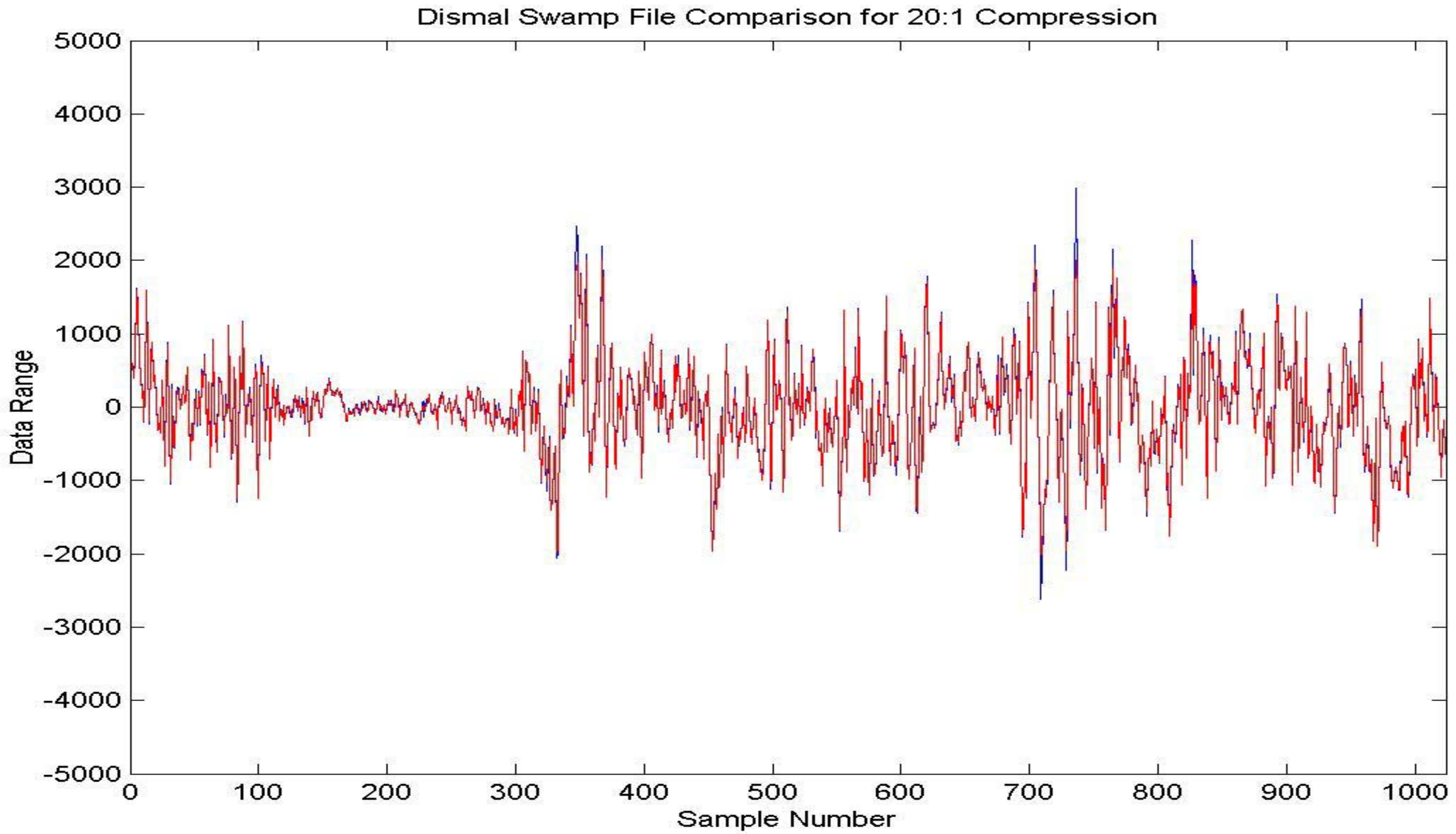
I&Q Data Comparison

20 to 1 Compression



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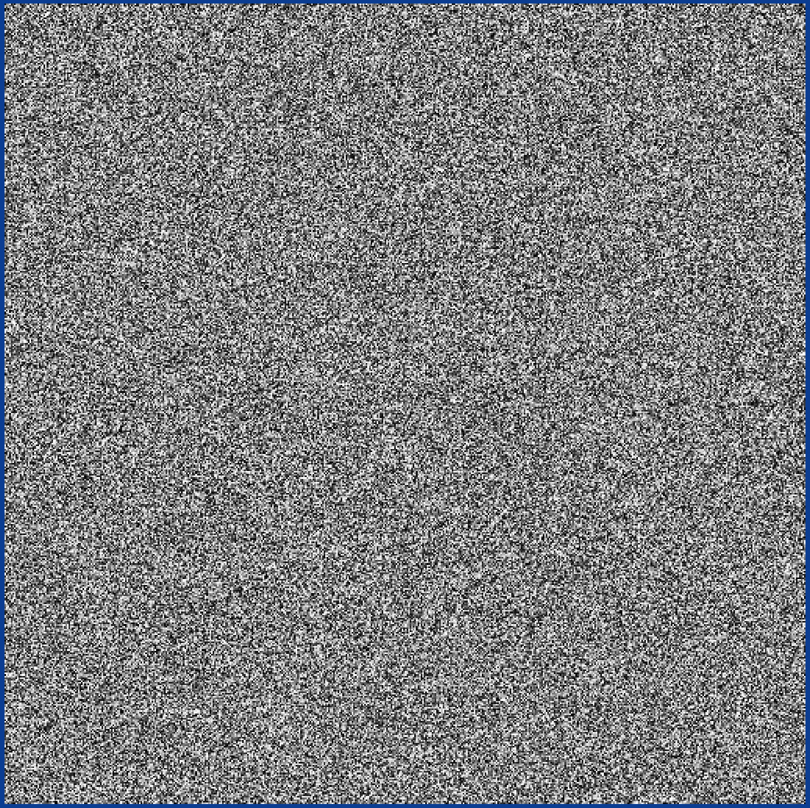
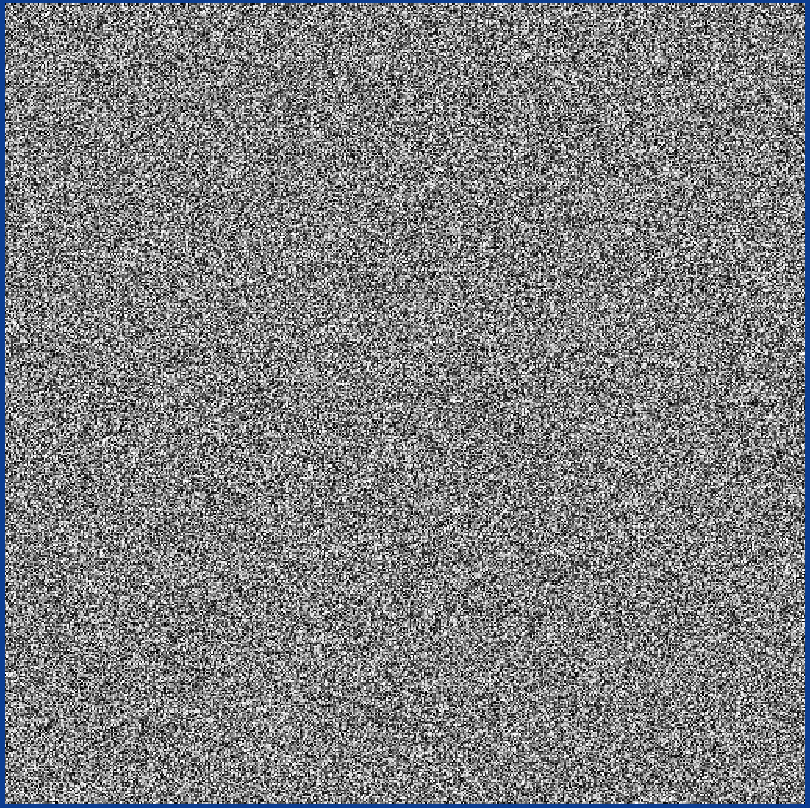
Phase Information

- Unlike the magnitude images, only limited information can be derived from the “images” and standard metrics generated from the phase data
- Solution was to generate a phase-derived product, a slant range Digital Elevation Map (DEM), from the original and decompressed data
- Elevation slices were then taken in both range and azimuth, and the original data was compared to the compressed data, at multiple compression ratios
  - The original data is plotted in blue
  - The decompressed data is plotted in red
  - As with the previous plots, red is overlaid on top of blue

Compressed Phase Data Representation



Original

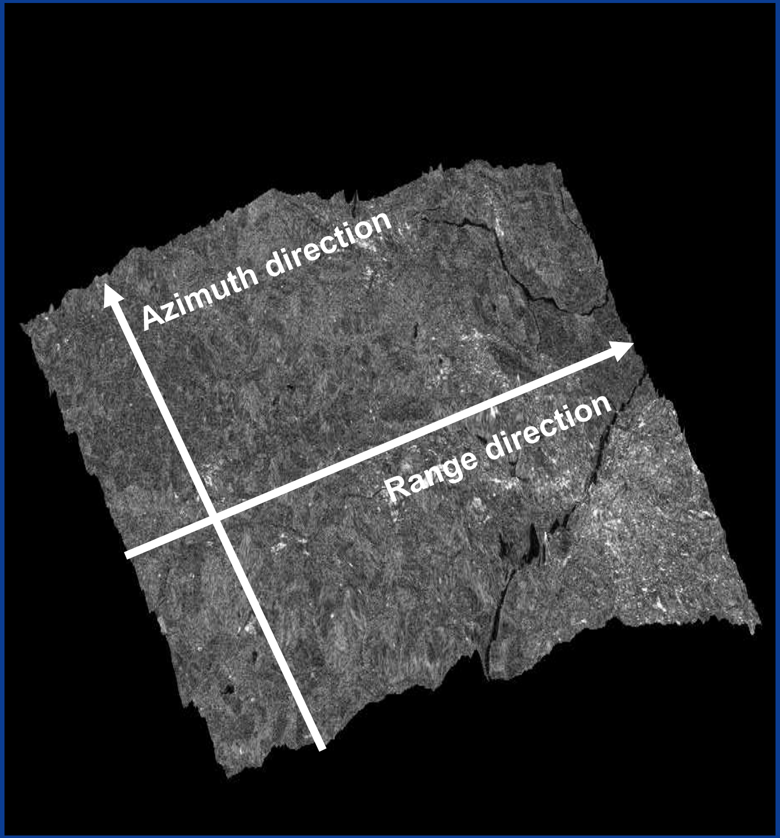


21:1 Compression

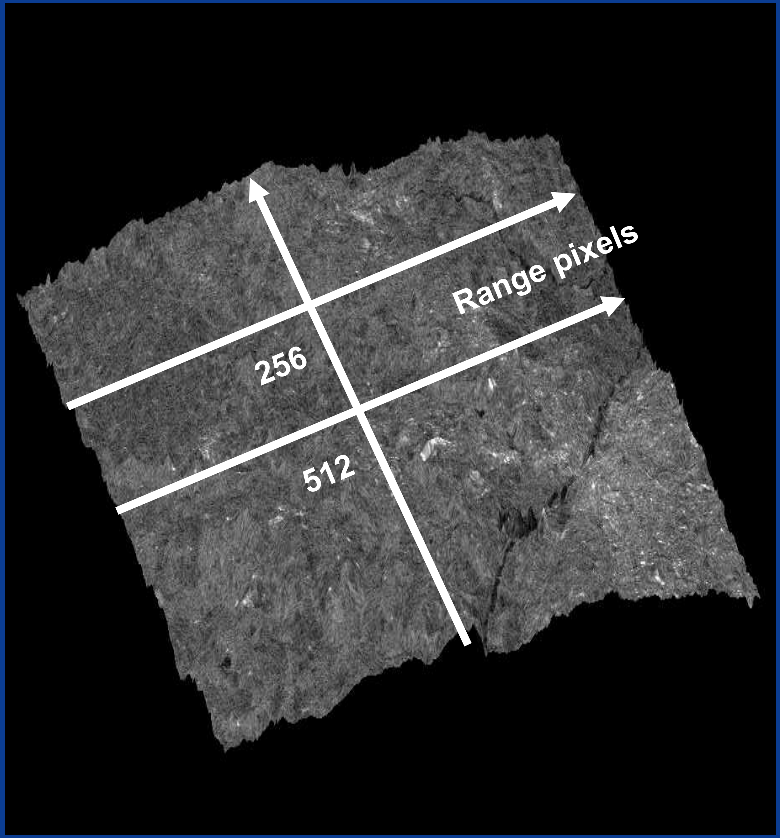
No useful visual information obtained from the Phase images

Phase-Derived Products

Original



21:1 Compression



The solution was to generate a Phase-derived product

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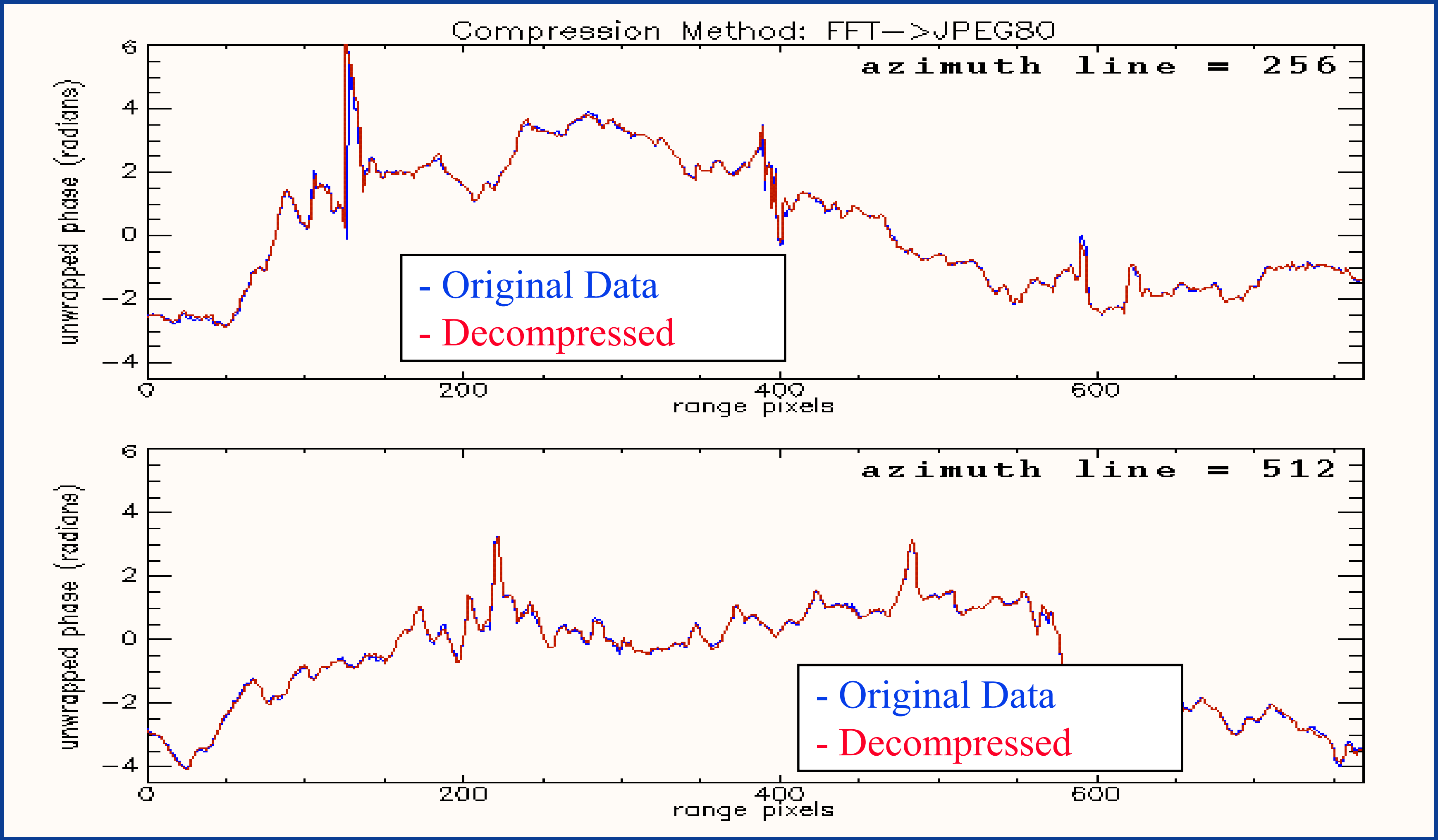
Slant Range DEM for Brittany

12 to 1 Compression Ratio – Azimuth Slice



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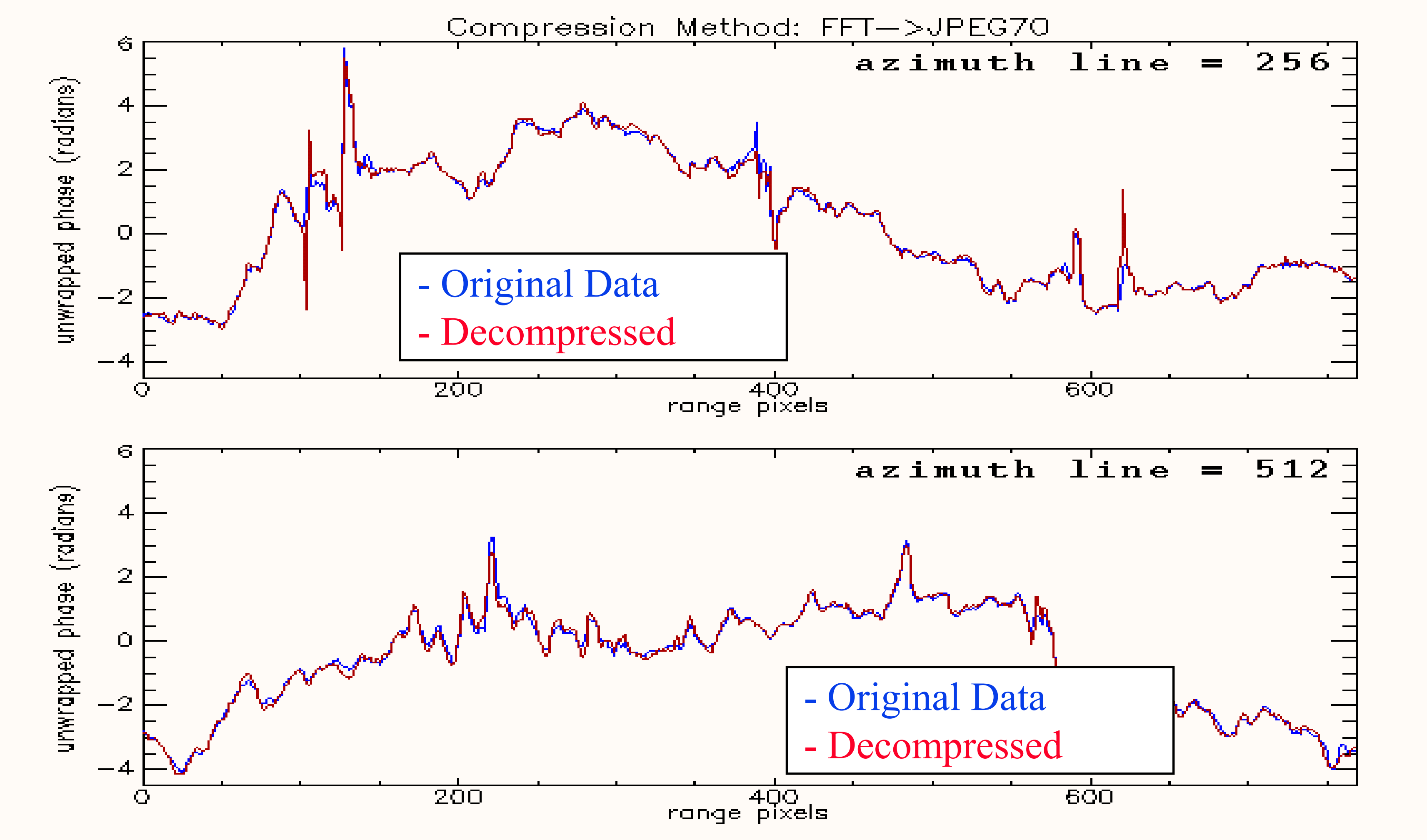
Slant Range DEM for Brittany

21 to 1 Compression Ratio – Azimuth Slice



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Summary

- Identified a need for a compression algorithm for complex SAR data
- SAIC sponsored IR&D developed a patent-pending compression algorithm
- Demonstrated that compression ratios of > 20 to 1 are achievable for complex SAR data
- Algorithm preserves both the magnitude and phase information. This was confirmed by:
  - Visual analysis
  - Overlay plots
  - Application of standard metrics
  - Generation of phased derived products

Summary

- Applicable for both raw VPH and processed SLC datasets
- Successfully compressed Polarimetric data
- Applications include data transmission, archival, and storage

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