Integrated Applications of Fiber-Optic Distributed Acoustic and Temperature Sensing

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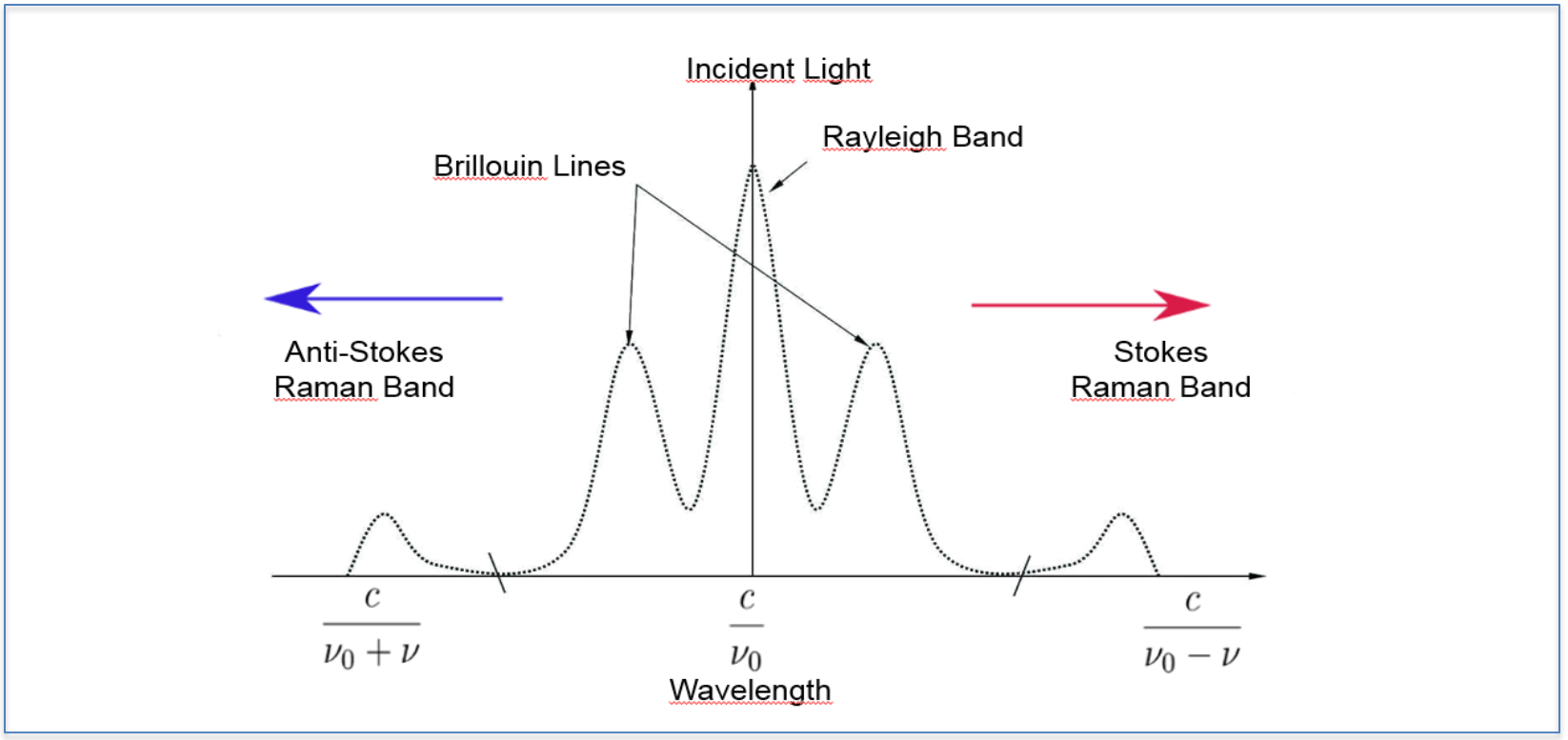
Contents

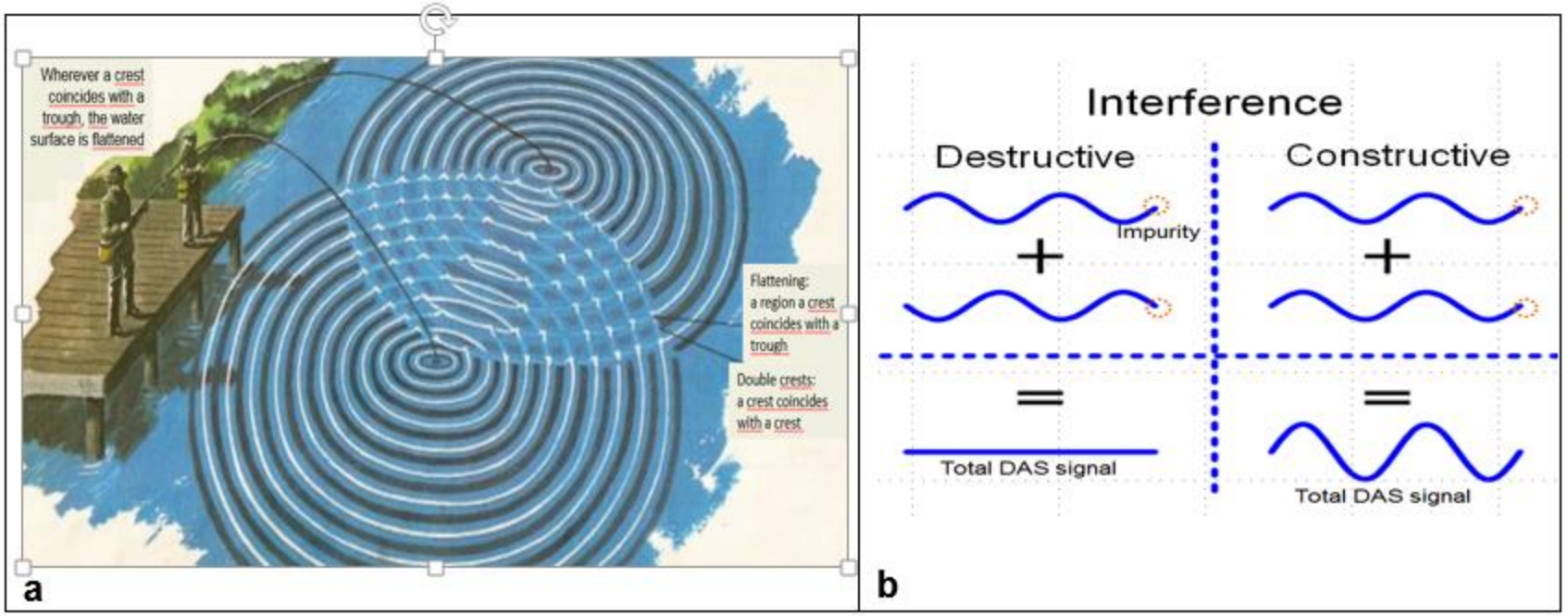
- Fiber-optic DTS and DAS principles
- Fiber-optic DTS and DAS Field Operations and Data management
- DTS and DAS current applications worldwide
- Summary
- Acknowledgements

Fiber-optic DTS and DAS principles



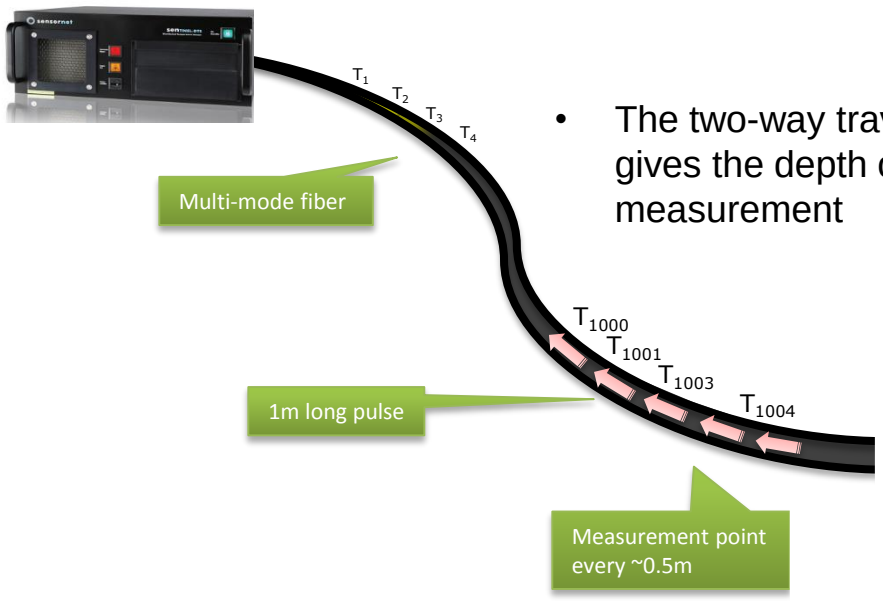
Raman and Rayleigh scattering peaks as function of the intensity, classic DTS measurement principle (the figure is not in scale).

Fiber-optic DTS and DAS principles



Backscatter from two impurities in the fiber and the concept of interference: a) analogy to throwing stones into a pond. b) The spatial separation is so that the backscatter results in destructive interference (no signal), and when the backscatter interfere constructively (enhanced signal).

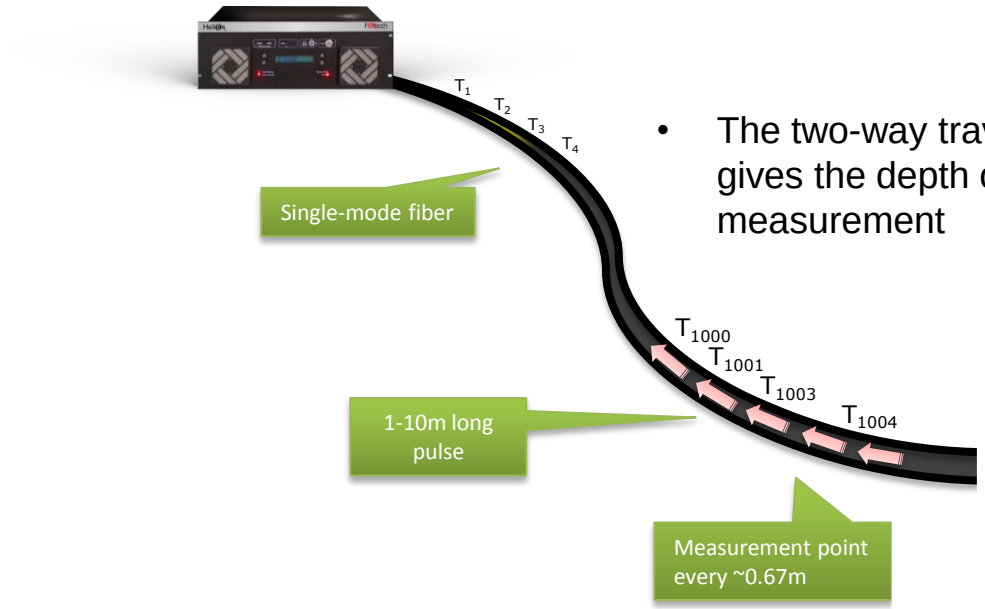
Fiber-optic DTS principles



- The two-way travel-time of the light gives the depth of the temperature measurement

Schematics showing the operational layout of a fiber-optic.
DTS pulses of light are launched (from the interrogator) into the sensing fiber 1000's of times per second.

Fiber-optic DAS principles



- The two-way travel-time of the light gives the depth of the acoustic measurement

DAS acquisition interaction between the interrogator and the fiber itself. Pulses of light are launched (from the interrogator) into the sensing fiber 5,000 or 15,000 of times per second. Data size recorded will depend on the sensing program objectives, target depth and recording time (duration of each phase).

Fiber-optic DTS and DAS Field Operations: Sensing Program

a

A-priori Information

- Completion schematics
- Well trajectory
- Target depth
- Objectives and challenges
- Platform space layout
- Production and or injection history
- Work over reports
- Well status and real time flow data

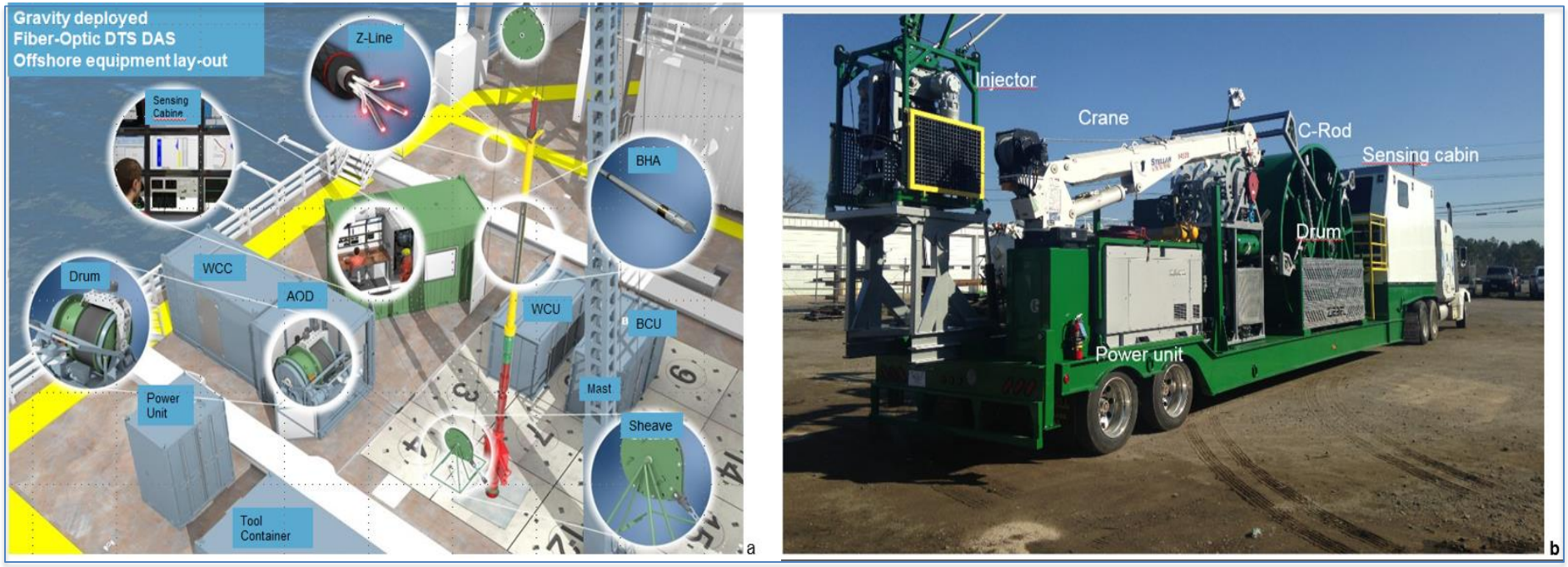
b

Injection	Baseline	Injection 1	Injection 2	Shut-in	Extended Shut-In	
Production	Baseline	Production 1	Production 2	Shut-in		
Well integrity *Extended Program*	Baseline	Bleed-Off 1	Build-up	Production	~~Bull heading?~~	Bleed-off 2	Build-up 2?

c

Sensing	Production	Injection	Well integrity	Flow Analysis	Conformance	Overburden	Seismic	Production optimization	Non-Conventional	Re-fracking Re-juvenation
Baseline[1]	V	V	V	V	V	V	V	V	V	V
Injection[2]		V	V	V	V	V	V		V	V
Production [3]	V		V	V		V	V	V	V	V
Shut-in[4]	V	V	V	V	V	V	V	V	V	V
Bleed Annulus A[5]			V			V			V	V
Build-up A[6]			V			V			V	V
Bleed Annulus B[7]			V			V				V
Build-up B			V			V				
Pressure up[8]			V			V				V
Bleed Annulus C			V			V				
Build-up C			V			V				
Thermal tracers[9]		V			V					

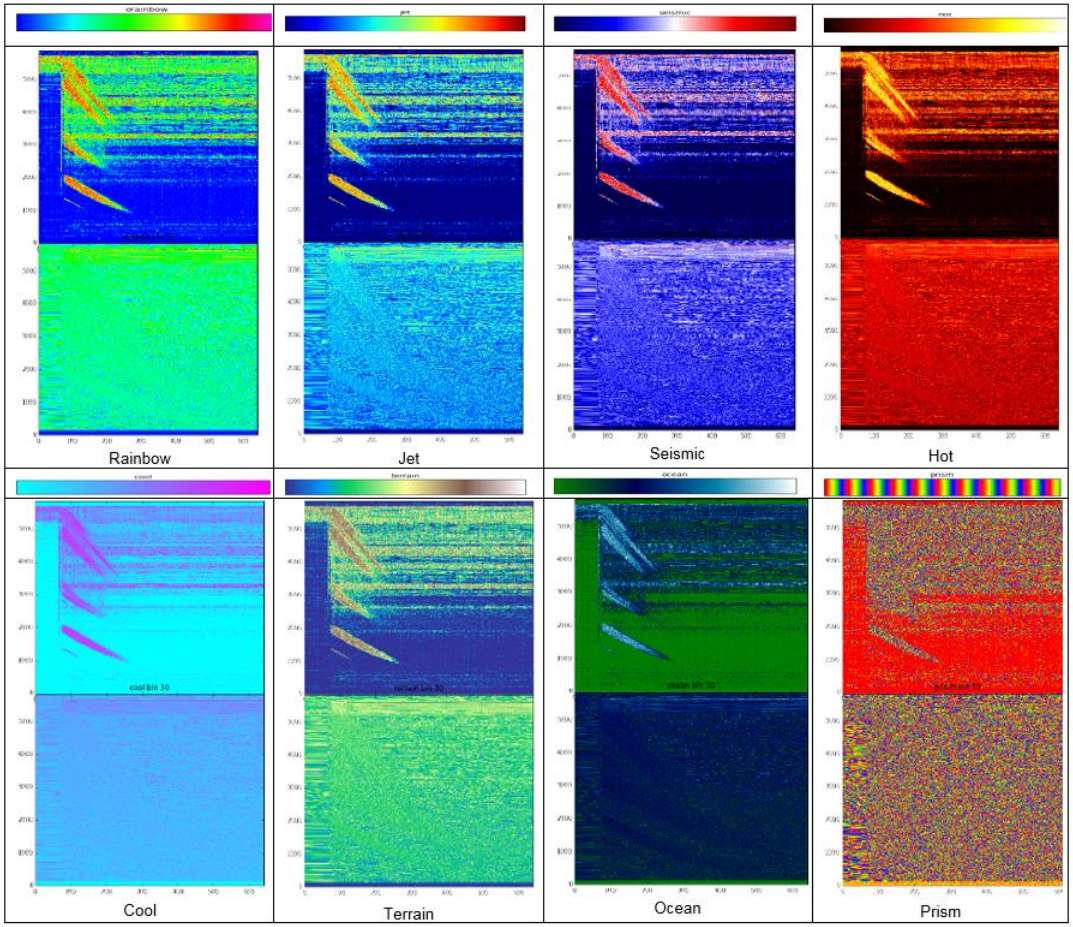
Fiber-optic DTS and DAS Field Operations



Field acquisition units. a) Offshore lay-out, showing the sensing components for a gravity deployed fiber-optic DTS DAS field operation unit, here fiber optic contains six fiberoptical cables, bottom hole assembly (BHA), BOP contro. b) On-shore standalone field acquisition unit, similar modules in one 20-ton mobile unit. Similar layout for a semi-stiff carbon road (Z-Rod) fiber-optic system.

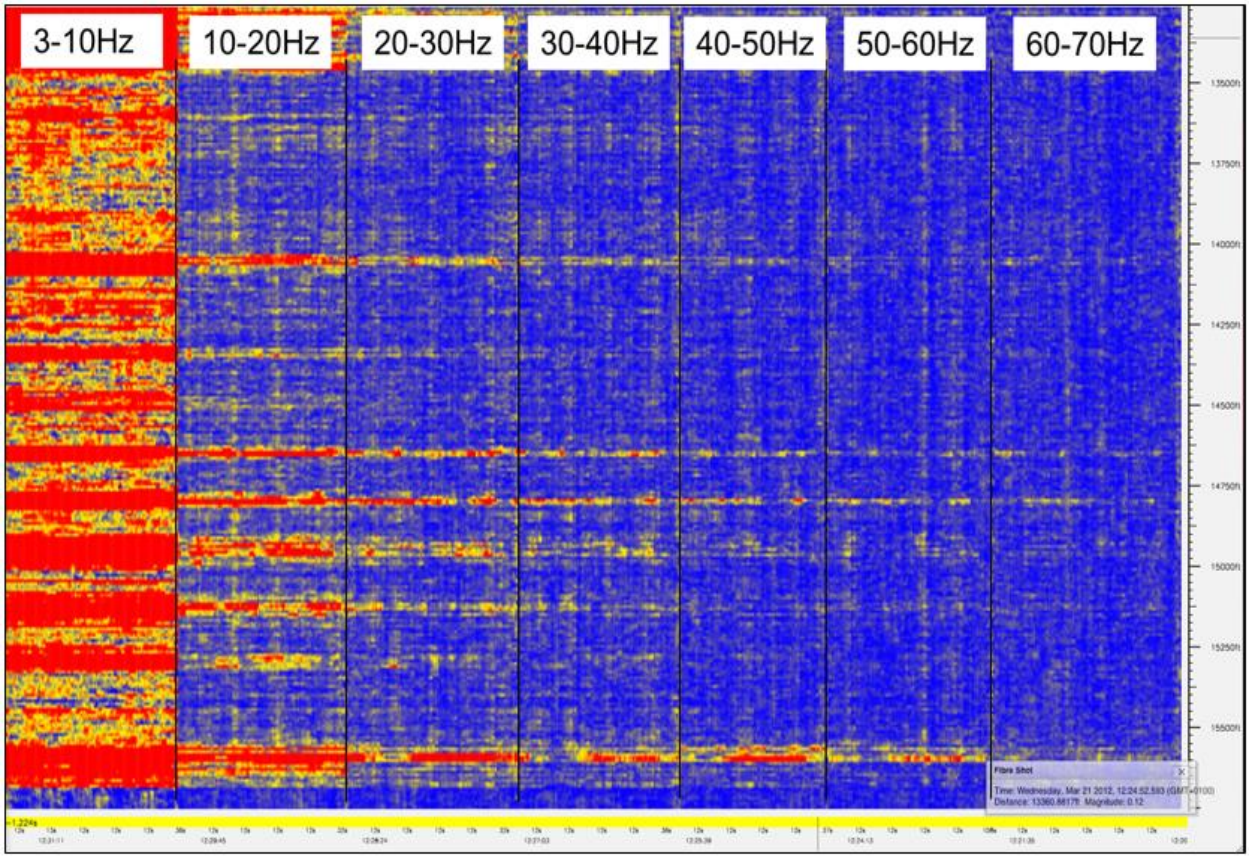
Fiber-optic DAS Feature Highlight Techniques

Feature highlighting techniques, showing only a partial set out of a multiple selection choices offering a wide range of options to visualize DAS processing results, band pass filtering, attribute mapping, to enhanced DAS event identification, observation, resolution and interpretation.

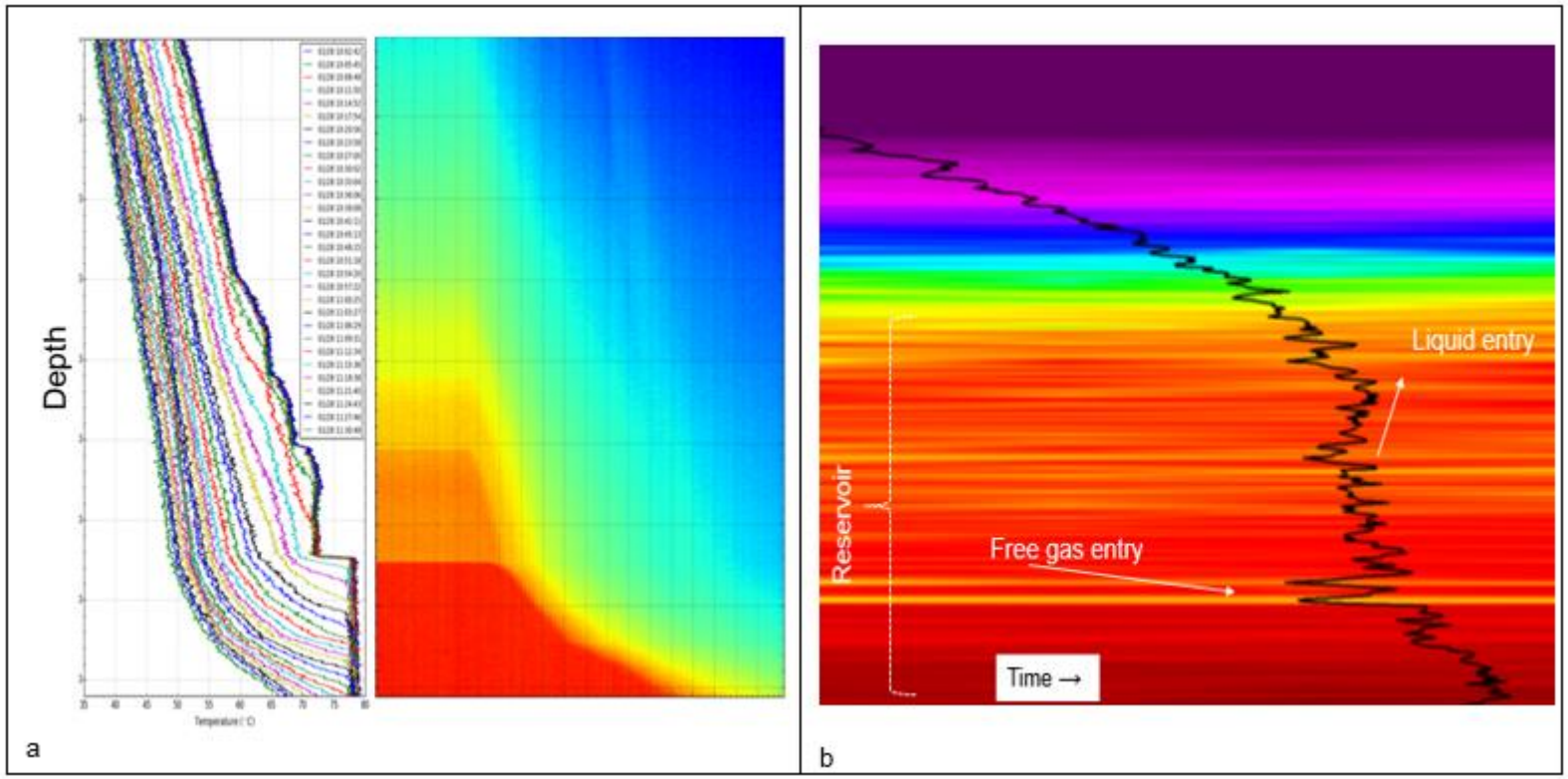


Fiber-optic DAS Feature Highlight Techniques: Frequency Filtering

Example of a real-time DAS image and displayed after applying frequency-filtering options.

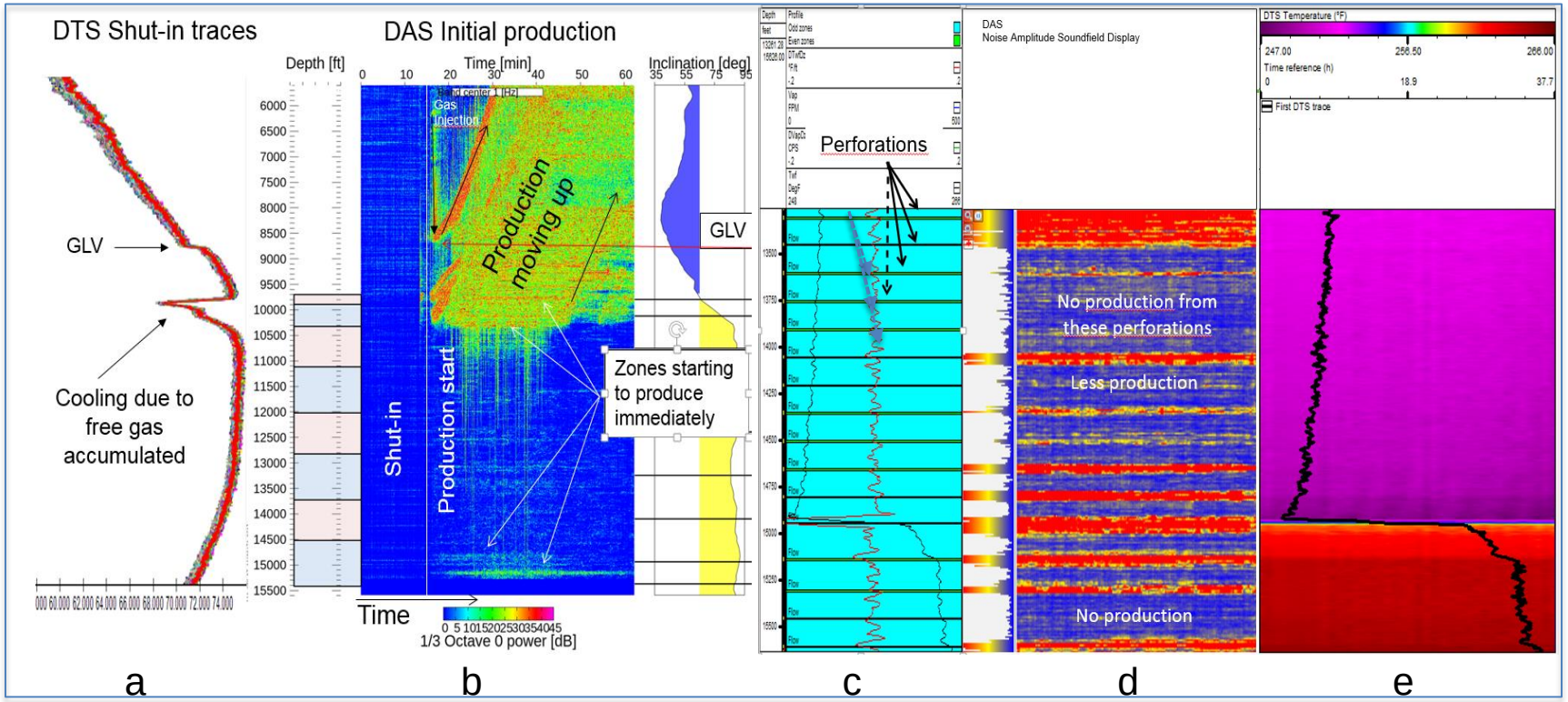


DTS and DAS current applications worldwide: Injection and Production



DTS applications. a) Injection mode: DTS waterfall display showing an initial hot-slug as a function of time (1.5 hours). Improved DTS data allow for a fast analysis of injection volumes and easy decision on injectivity performance at respective zone of interest. b) Production mode, a 4 hours production DTS data, showing the reservoirs interval, free gas entry zones (cooling effect) and liquid entry, here the thermal zonation will allow for a fast turnaround flow allocation analysis.

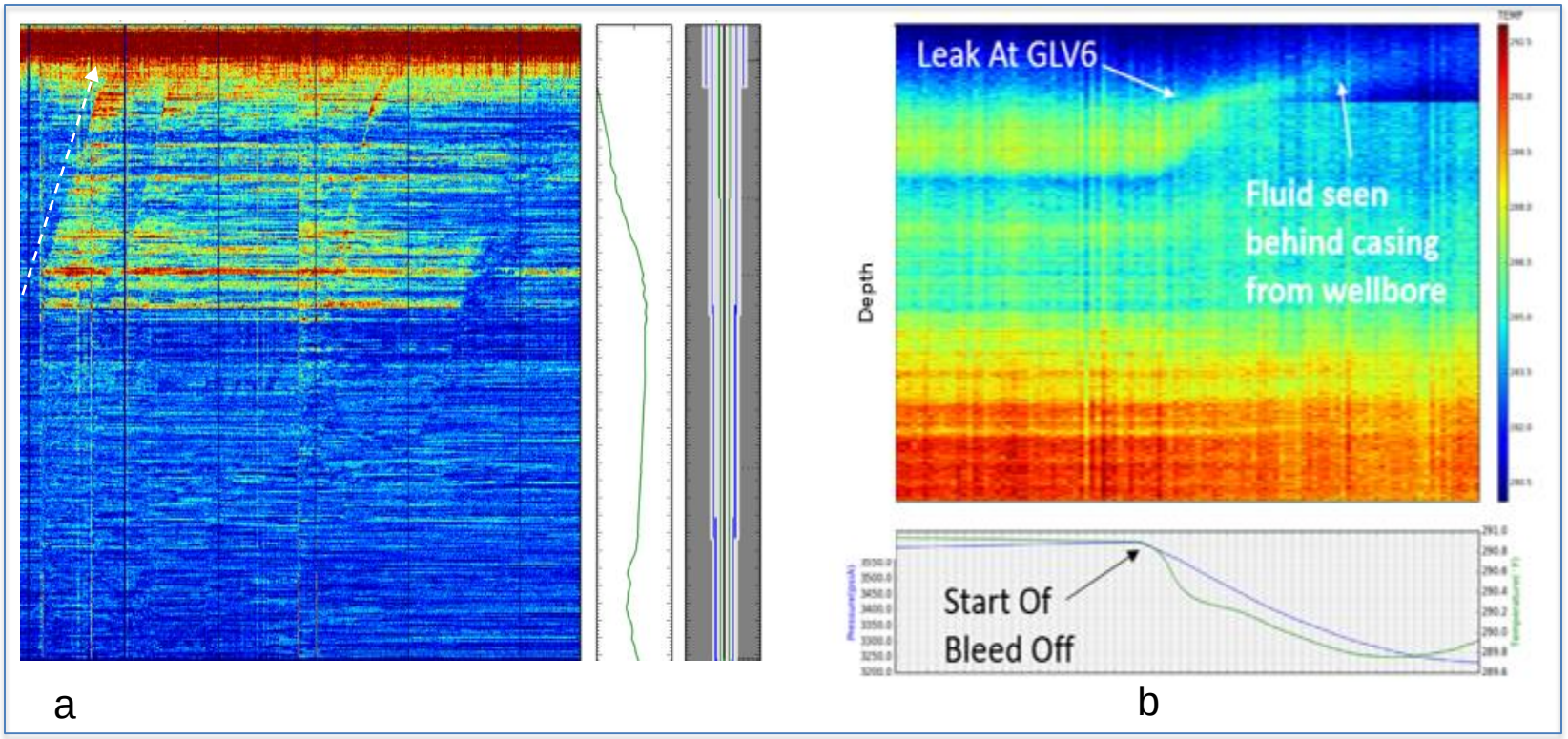
DTS and DAS current applications worldwide: Production



a) DTS traces showing a temperature anomaly, cooling due to free gas, also the GLV location and its temperature response, and b) DAS image, free gas flowing from the upper two sliding sleeves. c) Fiber-optic entered safely through a restriction where small ID wireline tools could not enter. The green lines indicates the location of the perforations, d) DAS real time image showing the contributing perforations, and e) DTS waterfall display showing the water-producing zone.

DTS and DAS current applications worldwide: Well Integrity

Gas entry point



Well integrity mode DAS and DTS images. a) Allow tracking deep gas leaking from source in the annulus A. b) A-annulus bleed-off reveals a leaking gas lift valve.

Summary

Fiber optic DTS and DAS technology offers solutions to acquire enhanced data with applications to production flow, completion and hydraulic fracture monitoring operations in real time during the asset lifecycle.

The possibility of observing the entire wellbore simultaneously in real time is providing the necessary information to learn more about for instance leak behind casing and other integrity issues.

Acknowledgements

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