Beyond DAS: Advances in Distributed Rayleigh Sensing

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Presentation Overview

**Introduction**
- AP Sensing
- Products and Services

**Technology**
- DAS Concept
- DAS Terminology
- Phase vs Amplitude

**Case Study**
- Enhanced DTS
Company History

1939  Hewlett-Packard (HP) started as a test and measurement company.

1959  HP establishes its first production site outside of the US in Boeblingen, Germany.

1999  The measurement business from HP is spun off into Agilent Technologies.

2007  The fiber optic monitoring business is spun off to create AP Sensing.
Global Presence

- Houston, USA
- Basingstoke, UK
- Boeblingen, Germany
- Bahrain
- Shanghai, China
- Seoul, Korea
- Singapore
- Headquarters
Established Markets

- Power Cable Monitoring
- LNG Monitoring
- Fire Detection
- Pipeline Monitoring
Established Markets

Well & Reservoir Monitoring

Train & Rail Monitoring

Geo- and Hydrological

Perimeter Security
## R&D % of Revenue

<table>
<thead>
<tr>
<th>Company</th>
<th>% of Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel</td>
<td>20%</td>
</tr>
<tr>
<td>AP Sensing</td>
<td>17%</td>
</tr>
<tr>
<td>Google</td>
<td>13%</td>
</tr>
<tr>
<td>Siemens</td>
<td>6%</td>
</tr>
<tr>
<td>Samsung</td>
<td>6%</td>
</tr>
<tr>
<td>Apple</td>
<td>3.5%</td>
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</tbody>
</table>

## Code Correlation

- **8 km** Single receiver
- **12 km** Dual-Ended
- **8 & 12 channel** Modbus
- **12 km** DDW
- **8 km** VdS
- **12 km** GeoDTS
- Low power
- Outdoor

## Technology Timeline

- **2004**: Code Correlation
- **2006**: Low power
- **2008**: ATEX Configurator
- **2010**: SmartVision 1.0
- **2012**: MultiSensorBoard
- **2014**: VdS 24 channel
- **2016**: Integrated Modbus
- **2018**: Hibernation Mode

## RTTR

- **DAS A**: 4x speed, 30km SM, 50km MM, RTTR 7.0
- **DAS B**: 10x speed, 70km SM, 70km MM
- **DAS C**: Safety tester, SmartVision 3.x

## Standards

- **IEC-104**
- **Modbus** TPC 24 channel
- **UL521**
- **OPC / DNP3**
- **Hibernation Mode**
- **24 channel**

## Performance

- **30km MM**
- **40km MM**
- **50km SM**
- **50km MM**
- **70km SM**
- **70km MM**
- **10x speed**
- **RTTR 7.0**

## Safety

- **SIL 2**
- **RTTR 7.0**
AP Sensing Solutions

Instruments
- DTS
- DAS

Enclosure
- Wall Mount
- Low Temperature

Rack Solutions
- Redundant Systems
- Networking
- UPS
- Backup Solutions
- Operator Displays

©AP Sensing
Leading the Way with Passion.
AP Sensing Solutions

RTTR (DCR) Engine

Insight View™

Asset View™

Data Server & Smart Capture™

Protocol Interface

Multi Client

Smart Alarm™

Modbus IEC 60870 DNP3 IEC 61850 OPC
Powerful Analysis and Configuration Tools

- Rules
- Machine Learning
- Fibre Configuration
SmartVision MapView

- Live data can be displayed either on satellite image or conventional schematic representation
- Train data including position, velocity and length can be displayed
- Cars at road crossings and pedestrians can also be monitored and displayed
Technology
DAS Measurement

DAS is an OTDR based technology. The position of the acoustic/vibration event is determined by measuring the arrival time of the returning light pulse, similar to a radar echo.

The coherent Rayleigh effect is stimulated by minute strain changes in the fiber as a consequence of thermal, acoustic, vibration or strain effects. The returned signals are analyzed and presented in the form of frequency and amplitude of disturbance.
Terminology

- Coherent Fading Noise
- Coherent OTDR
- Coherent Rayleigh Noise
- Distributed Acoustic Sensing (DAS)
- Distributed Vibration Sensing (DVS)
- Phase DAS
- Coherent Rayleigh Effect
- CRN
Technology


Technology

The transfer function is actually varying depending on the local scattering.

Technology

- Acoustic signal generates a disturbance in the 1D speckle
- Disturbance has a random sensitivity and direction
- Good for locating events but not suitable for reproducing applied signal

Amplitude Measurement
Technology

Dual Pulse Technique

Laser → Pulse Generation → Optical Amplifier → Backscatter Signal → Fiber under test → Receiver → Data Acq. → Processing

Carrier Frequency $\Delta f$

Fiber under test

Gauge Length

$\Delta f$
Technology

The output is proportional to the input.
Technology

- Acoustic signal generates a disturbance in the 1D speckle
- Disturbance has a known and repeatable sensitivity and polarity

Phase Measurement
Differential Phase Measurement
Signal Repeatability
DAS Performance Comparison

• Conventional DAS Technology
  - Non-linear signal response over distance and acoustic intensity
  - Can suffer from fading

• 2P Squared DAS
  - High SNR over 70 km measurement range
  - Linear response over distance & signal strength
  - Reduced Fading
Signal Linearity

Self-phase Noise

Dynamic Range / Linearity

Spatial Resolution
Advanced Signal Processing

The linear transfer between applied signal and the instrument output provides a much more robust prediction of events.

Prediction of class is based on proximity to the centroid of each class in different hyperplanes.

Most likely Blue Event
Distributed Rayleigh Sensing

Lower Noise
Improved Dynamic Range

Frequency Spectrum (Hz)

<table>
<thead>
<tr>
<th>$10^{-4}$</th>
<th>$10^{-3}$</th>
<th>$10^{-2}$</th>
<th>$10^{-1}$</th>
<th>$10^{0}$</th>
<th>$10^{1}$</th>
<th>$10^{2}$</th>
<th>$10^{3}$</th>
<th>$10^{4}$</th>
<th>$10^{5}$</th>
<th>$10^{6}$</th>
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</thead>
<tbody>
<tr>
<td>Temperature Strain</td>
<td>Earthquakes</td>
<td>Rock Movement</td>
<td>VSP Microseismic Leaks</td>
<td>Acoustic Emissions (Rock) Sand Detection</td>
<td>Acoustic Emission (Metals)</td>
<td></td>
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</table>

DC

Current

Established

Value

Extending DAS Applications

Physical

Audible

Conventional DAS Measurements

24
Case Study
Enhanced DTS (eDTS)

Distributed Temperature Sensors based on Raman scattering provide reliable, robust measures of the absolute temperature of the optical fiber.

Distributed Rayleigh Sensors can provide a measure of the changes in temperature of the fiber in short periods of time.

Combination of Raman DTS and DAS produces a system with improved performance both in response time and in temperature resolution.
Visualisation .. DAS Configurator

Standard FBE Output

DTGS Temperature Output

Test set up – with one fiber
Integration .. Enhanced DTS Measurement
Acoustic vs Temperature .. Amplitude

Two key factors
- Temperature changes are slow
- Phase changes due to temperature are large – generally much larger than acoustic signals

Examples of signal magnitudes from Machine Learning Library Data
Enhanced DTS
Temperature Resolution

Improved temperature resolution and reduced measurement time at 69km

SmartVision

Spatial Resolution
Measurement Time
Range

2degC
30mins
69km
Enhanced DTS Measurement Time

DAS provides fast response
Each data point is 10 seconds

Time
Summary

- DAS terminology can be very confusing
- Not all DAS systems are the same
- Performance of a DAS where the output is linear and repeatable with the input offers significant advantages
- The low frequency output of the DAS is predominantly temperature and can be used to enhance the Raman DTS measurement to provide either an improved temperature resolution or a faster measurement output
- Exciting and evolving field with many advances to come
Questions?

References


