DTS Standard

Date: 20 May 2007

1. Scope

This document specifies a test method for characterizing and reporting Distributed Temperature Sensor (DTS) performance. DTS systems are designed to measure temperatures at regularly sampled intervals along the length of a fiber optic probe.

The purpose of this test procedure is to establish a standardized method that can be used worldwide to measure and report the performance of DTS products.

2. Definitions

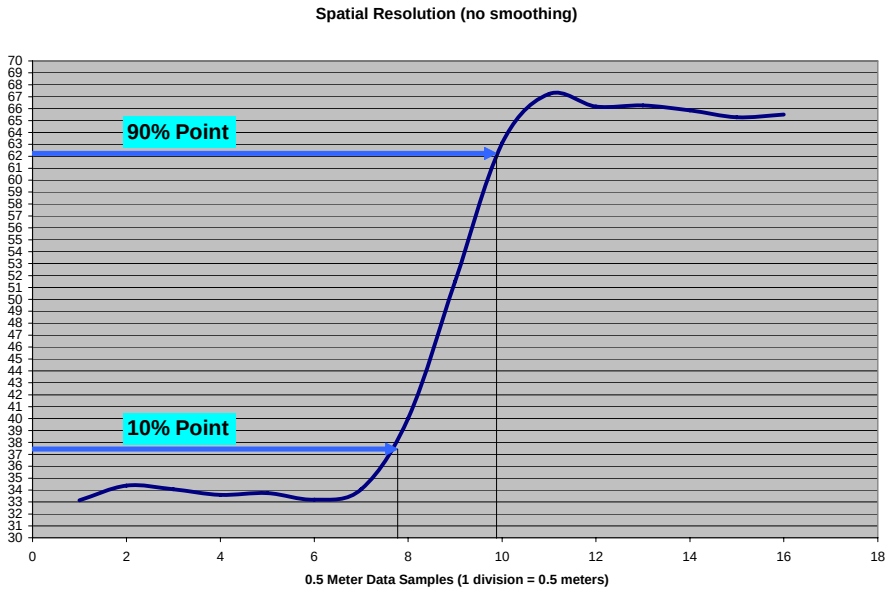
For the purpose of this document the following definitions apply:

a. Sampling Resolution

The distance between consecutive temperature data points along the fiber probe.

b. Spatial Resolution

The distance required to measure a step change in fiber temperature. The transition is defined as taking place when the temperature has gone from 10% of the change to 90% of the change. See the chart below.

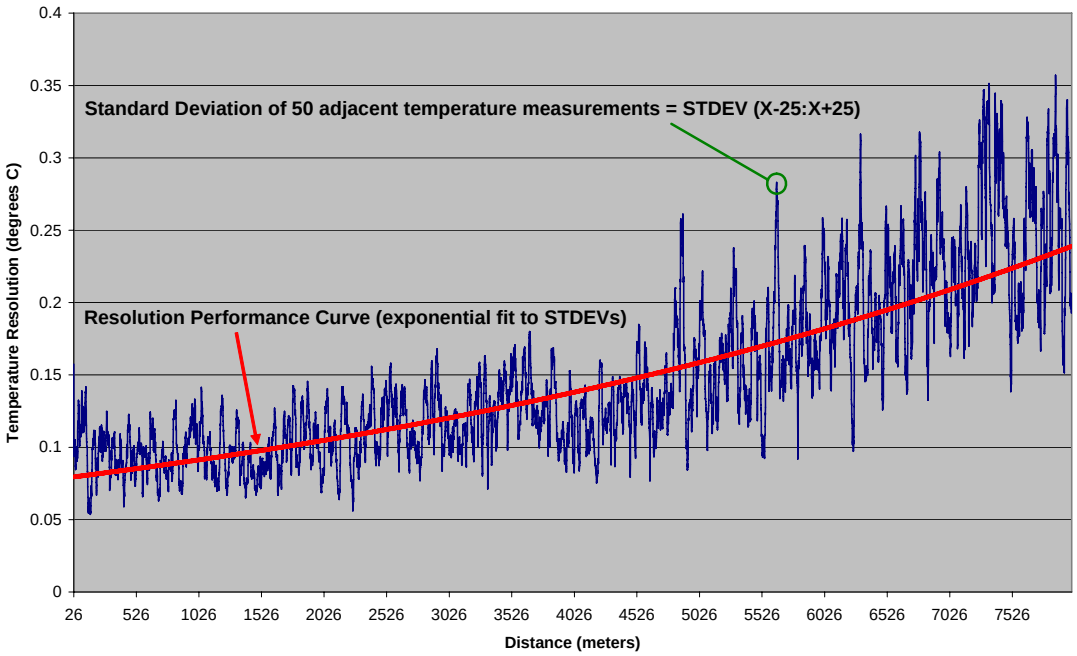


c. Measurement Time

The period of time required for the DTS to make a measurement of a specified temperature resolution with specified spatial and sampling resolutions over a specified length of fiber probe. When making continuous measurements, this is the time interval in which the temperature data is renewed.

d. Temperature Resolution

This is described by a simple exponential curve which represents the trend for the running 50 point standard deviation values of temperature data as measured with the entire fiber probe at a temperature of 20°C. See the chart below.



e. Temperature Accuracy

This is the maximum difference between any running temperature average over 50 meters and the probe's actual temperature. This is measured over the entire length of the fiber probe. Temperature accuracy can only be measured after the DTS has been properly calibrated.

f. Optical Budget (loss)

This is the loss (in dB, measured at 1300nm) that the DTS can tolerate in the fiber probe and achieve the stipulated Temperature Resolution. This is the summation of losses due to splices, connectors, switches, and fiber in one direction (1 way loss).

g. Operating Temperature Range

This is the range of environmental conditions over which a properly calibrated DTS can meet its reported performance specifications.

h. Temperature Range

This is the range of fiber probe temperatures over which the DTS can be configured to make measurements. [Note: various fiber probe types will have dramatically different lifetimes as a function of probe conditions (specifically probe temperature and pressure).]

i. Average Power Consumption Calculation

This is the calculation of the average power consumption of the DTS to achieve a stated temperature measurement. It is calculated from the power consumptions of both the read and idle (non-read) periods for the stated temperature measurement.

The stated temperature measurement shall be specified in terms of temperature resolution, measurement time, measurement temperature, and system optical loss (1-way @ 1300nm). Against the stated temperature measurement the following will be given:

P_{idle}	power consumption during idle period (W)
P_{read}	power consumption during read period (W)
S_{read}	actual read period (seconds)

The calculation of Average Power Consumption (P_{avg}) shall be calculated for a stated temperature measurement as follows:

$$P_{avg} = \left[P_{read} * \frac{S_{read}}{S_{spec}} \right] + \left[P_{idle} * \frac{(S_{spec} - S_{read})}{S_{spec}} \right]$$

Where;

P_{avg}	=	average power consumption (W)
P_{read}	=	power consumption during actual read period (W)
P_{idle}	=	power consumption during idle period (W)
S_{read}	=	time required for read (seconds)
S_{spec}	=	specified measurement time by client (seconds)

By way of example, for a stated temperature measurement with a specified measurement time of 400s, power consumption during idle of 10W, power consumption during read of 100W, and an actual read time of 100s (time required to actually achieve stated temperature measurement) the average power consumption would be calculated as follows:

$P_{avg} = (100 * 0.25) + (10 * 0.75) = 32.5W$

j. Maximum Power Consumption

This is the maximum power that can be drawn by the DTS.

k. Distance Measurement Range

This is the maximum distance over which the DTS can collect data at a stated sampling resolution.

l. Short Term Stability (24 hours)

Short Term Stability is defined to evaluate the stability of each spatial point for short term, hereon 24 hours. The measured entire fiber shall be held at a controlled temperature of +20 deg.C and the DTS unit shall be tested at +20 deg.C, the minimum and the maximum Operating Temperature Range. The maximum value of a simple exponential curve, which is calculated distance versus one standard deviation over 24 hours of a single spatial point, is reported as the Short Term Stability. It is proposed that the Measurement Time is 10 minutes and the number of data for calculating one standard deviation is each 144.

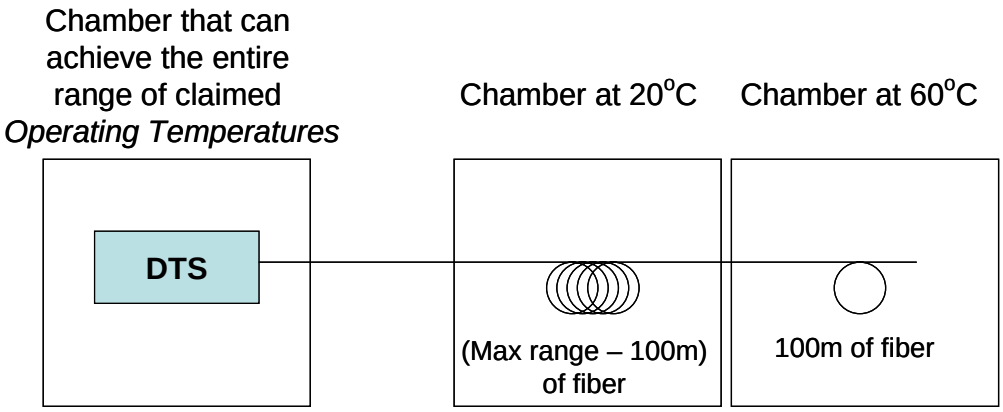
3. General Conditions for Measurement

a. General

All measurements should be made under test conditions as specified below.

b. Test Configuration

The DTS characterization should be conducted using three chambers that are capable of holding their internal temperature at +/- 0.5°C. The first chamber should be able to hold the DTS system and should be capable of generating the complete range of temperatures claimed as the system's *Operating Temperature Range*. The second chamber should be able to contain a length of fiber equal to 100 meters less than the systems claimed *Distance Measurement Range* and should be able to operate at 20 °C. The third chamber should be able to contain a 100 meter length of fiber and should be able to operate at 60 °C. Below is a diagram of the set up.



c. Probe Fiber

The fiber optic probe should be a standard graded index 50/125 acrylate fiber. The length of the fiber probe should be equal to or greater than the *Maximum Range* claimed. The fiber should be terminated according to the DTS manufacturer's recommended method. The fiber probe must be plugged into the DTS using a connector that is compatible with the socket style that is normally supplied on the DTS. The fiber probe's length should be determined using a properly calibrated OTDR.

d. Measuring Equipment

Temperature and power measurements shall be made with suitably calibrated test equipment. All centerline temperature measurements shall be made to +/- 0.05°C. Power measurements shall be made with an uncertainty of less than 2%.

4. Measurement Approach

a. Preparing for the Test

Install the DTS and fiber probe into the chambers with the temperature of the DTS chamber set to 20°C. Allow the temperature of each of the chambers to stabilize. Calibrate the DTS according to the manufacturer's guidelines. If applicable, set the DTS sampling resolution and spatial resolution to the values for which the characterization is being performed.

b. Measuring Spatial Resolution

Collect a temperature trace using the DTS that has a temperature resolution of at least 1°C at the maximum temperature range. Use this data collected at the transition from the second to the third chambers (20°C to 60°C) to measure the system's spatial resolution as defined in section 2 above. If the System has variable spatial resolution and sampling resolution settings, the values used should be specified when the data is presented.

c. Measuring Temperature Accuracy

Collect a temperature trace using the DTS that has a temperature resolution of at lease 1°C at the maximum temperature range. Use this data to measure the system's temperature accuracy as defined in section 2 above.

d. Measuring Temperature Resolution

Set the DTS to collect data traces at each of the *Measurement Times* to be characterized. Use the data collected along the fiber section in chamber 2 (with the fiber probe at 20°C) to measure the system's temperature resolution as defined in section 2 above. Data should be presented for different distances and sampling times with the spatial resolution and sampling resolution used clearly specified.

e. Measuring Short-Term Stability

Set the DTS to collect 288 consecutive 5 minute traces. Use the data to measure the system's short-term stability as defined in section 2 above.

f. Measuring Power Draw

Set the DTS to make a temperature measurement at the stated temperature resolution at the stated spatial resolution at a distance equivalent to an optical loss of 1.2dB @1300nm (1-way) with the fiber probe held at a temperature of 20C. Using a power analyzer, record the instantaneous power being consumed by the DTS every 5 seconds over the entire measurement time. Use the data to calculate the system's maximum power draw and the average power consumed to make the referenced measurement as described in Section 2 above.

g. Measuring Operating Temperature Range

Adjust the temperature in chamber 1 to the minimum operating temperature that is claimed and repeat the above testing. Ensure that chamber 1 has been at the new temperature for a sufficient time for the temperature of the DTS to stabilize. The stabilization of the DTS's temperature should be confirmed using a calibrated thermocouple prior to beginning testing. Following the low temperature data collection, the temperature of chamber 1 should be adjusted to the maximum operating temperature that is claimed. Once the temperature of the DTS has been confirmed via calibrated thermocouple to be stabilized at the new temperature, the system characterization testing should be conducted.

h. Optical Budget (loss)

An optical attenuator shall be inserted between the DTS and the fiber in chamber 2. Temperature resolution, spatial resolution, temperature accuracy, and short-term stability will then be reported as above at increasing optical loss levels. Optical loss will be measured as defined above in Section 2.

i. Temperature Range

These measurements may require the fiber probe to be changed to employ special fiber constructions. After the fiber is replaced, and the DTS properly calibrated to use the new probe, the temperature of the second chamber can be lowered to the minimum temperature to be claimed and performance data collected as described above. Next the temperature of the second chamber can be raised to the maximum temperature to be claimed and performance data collected as described above. In both cases, calibrated thermocouples should be used to confirm that the fiber probe in chamber 2 has actually reached the targeted temperature.