# Technical Note 135

## Overcoming 'Noise' And Establishing A 'Zero'

### Introduction

Turbidity measurements all suffer from a range of difficulties that need to be overcome. Two of these universal issues are overcome by TurbSense® by using an innovative approach to the signal processing - so innovative that Pi have a patent for it. This novel signal collection and processing method is called the 'MutoLux® method.

Click here to see an animation explaining the 'MutoLux®' method.

The issues to be overcome are;

1) errors and instability due to signals other than those coming from turbidity. This is referred to as 'noise',

and

2) establishing a 'zero' point on the calibration graph.

*Fig. 1 Pi's TurbSense® sensor.*

### 1) Instability due to 'noise'

'Noise' is defined as signals from a measurement that come from somewhere other than where you want them from. In the case of turbidity, the signal we want is from light scattered by 90° from the turbidity in the water. We don't want signals from stray light, from electronic noise/drift, or from an electronic or other offset.

### 2) Problems with establishing a 'zero' point

As in many measurement systems, most turbidity meters need at least two points on a graph to establish the relationship between the turbidity and the signal derived from the measurement (calibration). At high levels of turbidity, the potential error introduced by noise is small and so is not a problem. At low levels of turbidity, the signal generated by something that we don't want to measure is much higher as a proportion and so is a bigger problem.

The way to solve that problem is to measure the signal at '0' NTU and subtract it from all the measurements. It sounds simple but it isn't! Some manufacturers at the time of manufacture have a 'factory zero'. This can provide for the electronic noise at the time of manufacture but doesn't allow for drift in that noise over time or other noise such as stray light etc. The other way that manufacturers cope with this issue is by 'zeroing' their instrument. That is, they require the user to introduce 'zero' turbidity water. 'Zero' turbidity water is actually impossible to produce as even the water molecules themselves scatter light to give approximately 0.018 NTU. Ultra pure water that is often called 'zero' water is as close as can be achieved but is extraordinarily difficult to produce, and very easy to contaminate. This is why DI water is often used. However, DI water can vary in turbidity between 0.03 NTU and 0.1 NTU. The result of this is that any instrument that requires a 'zero' point is actually significantly wrong at the low end where it is often most important.

### TurbSense® has the solution in 'MutoLux®'

If there was a way to take a measurement that was only affected by the turbidity of the sample and not by 'noise' then there would be no reason to require a 'zero' sample and also no effect of drifting electronics or stray light on the reading.

Optical physics has the answer!

In a 90° nephelometric turbidity system, the signal at the detector is affected by both the amount of turbidity and the amount of light emitted. The relationships are both linear, so if you double the light or double the turbidity the signal at the detector doubles. Typically a turbidity sensor will plot detected light against turbidity (see Fig. 2) and will fix A by introducing a known turbidity sample and B by either fixing a 'factory zero' or requiring a 0 NTU sample to be introduced to the measuring system. The TurbSense®, however, measures the amount of light that is being put out into the sample so we can draw a graph of light output vs. detected signal (see Fig.3).

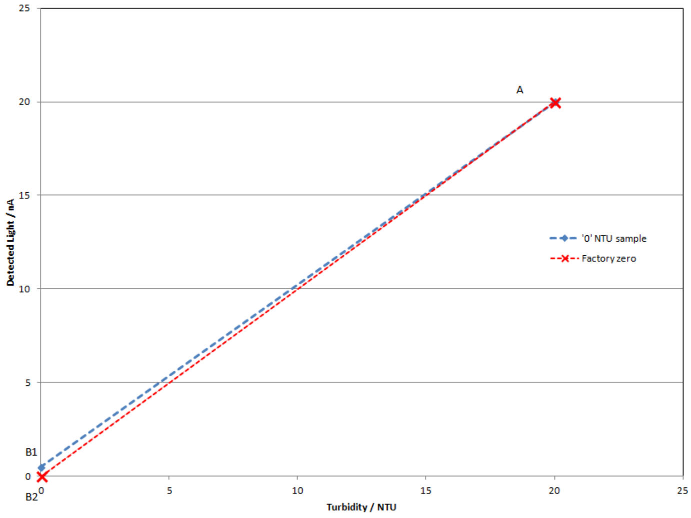


**Fig. 2 Detected light vs. turbidity.**

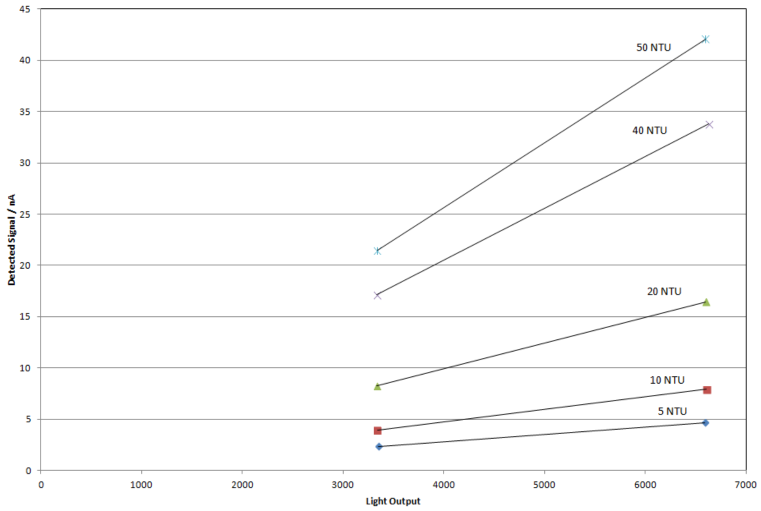


**Fig. 3 Relationship between light emitted and light detected with varying turbidity.**

If the readings are taken in quick succession the 'noise' can be assumed to be identical, so the gradient is independent of that 'noise'. The gradient of the line is therefore solely due to turbidity.

If a sample has no turbidity it will have a '0' gradient (the joys of physics!).

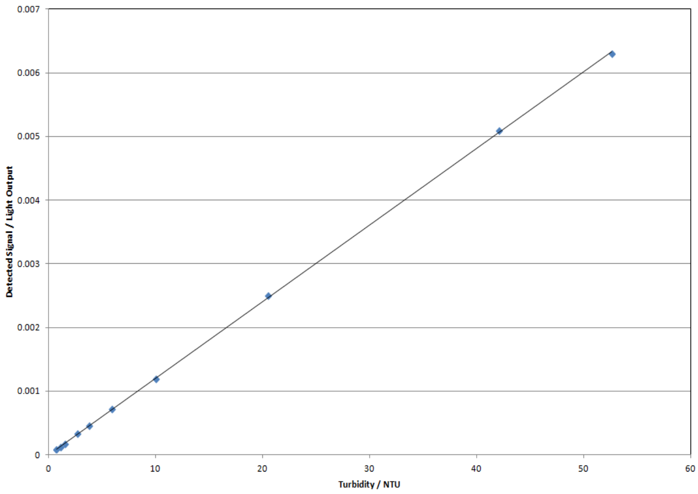


**Fig. 4 Relationship between light emitted/ light detected and turbidity.**

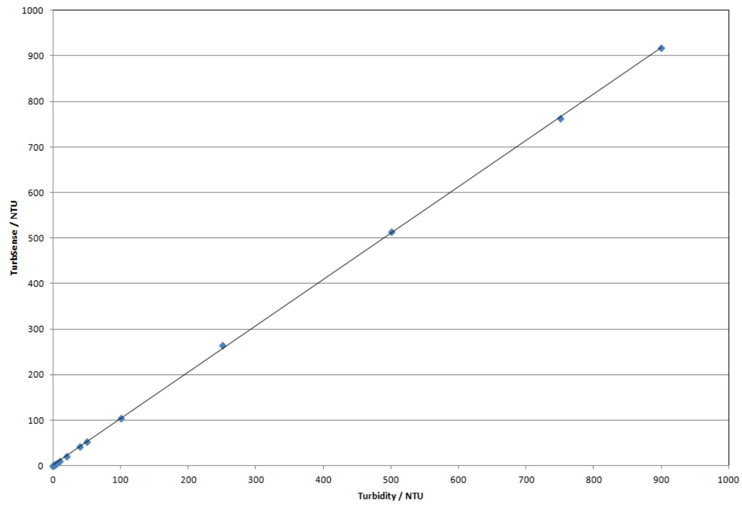


**Fig. 5 Comparison between sample turbidity and turbidity measured using TurbSense®.**

When the TurbSense® takes a reading, it does so at 100% light output, 75% light output, 50% light output and 25% light output. If there is no difference (gradient) then there is no turbidity. The bigger the difference the more turbidity there is.

This means that plotting the gradient (ie. light detected/light emitted) against turbidity gives us a calibration WITHOUT having to measure a zero, and don't forget that the zero (and the measurement) is independent of 'noise'.

Because of the innovative way the TurbSense® takes it's measurement it is equally suitable for a low range and a higher range.

Click here to watch an animation on how the 'MutoLux®' method works.