A Novel Signal Processing Method For The Nmi Water Calorimeter (Poster)

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Introductory Remarks Before the Poster Session

I'm Leon de Prez from the Netherlands Measurements Institute. Our poster is about a new measurement method for use for examination of the resistance changes in our water calorimeter. It will briefly describe the old method, which is used a lot in our ... laboratories using an ac bridge ... and why we have decided to change the method. ... We had some difficulties with the impedance measurement. The result was that we had to look for a different method. Also we encountered a lot of noise in the hospitals. Looking for a new method, getting information from our electrical standards laboratory, they gave us the idea to try to use the digital multimeter method, because they were convinced that the resolution of the multimeter was adequate ... for small resistance changes. So we did that. We just had to find a way to prove that the small measured resistance changes are in fact real resistance changes traceable to our national standards, and we did that by ... calibrating the resistance (at) two points and doing a check on the very small measurement range that we use for the calorimeter which is around 10 kohm. So we check the sensitivity of the multimeter, not by doing that with ... standard resistances, because they're not available in (those) small steps, but by checking the measurement voltage of the multimeter. Altogether that will give us a resolution step in ohms of about 300 micro ohm which will be for a 2 Gy irradiation, result in a 0.15% uncertainty contribution which is acceptable right now for our calorimeter. The electrical standards laboratory thinks that we can reduce that ... (by) probably a factor of two. But then we have to calibrate the digital multimeter against the primary electrical standards.

1. Introduction

The NMi has developed a water calorimeter as a new primary standard for absorbed dose to water in photon beams. This calorimeter is of the sealed-water type [1, 2], it is portable and is used in radiotherapy clinics to measure generic k_Q values [3].

The signal processing method for the water calorimeter employs a high precision digital multimeter (DMM). This method has been chosen instead of a Wheatstone bridge technique with lock-in amplifiers as used with our graphite calorimeter because detection of the small measurement signals[1] generated in a water calorimeter are difficult to measure using lock-in amplifiers.

2. Wheatstone bridge method

Figure 1 shows the AC-Wheatstone bridge as used with our graphite calorimeter and initially used with the water calorimeter. Two thermistor probes are connected each to their own bridge circuit. In the circuit, a variable resistance and thermistor are placed in opposite arms. The bridge is balanced each time before irradiation. Additionally, a variable capacitor compensates for parasitic capacity in the signal cables.

Employing the graphite calorimetry, the bridge is re-balanced during irradiation and the lock-in amplifier is used as a zero-detector. The total resistance change of a thermistor probe is determined using the difference of the balancing resistor and the change in offset voltage of

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[1] The temperature rise in water is approximately 5 times smaller than that in graphite for ^{60}Co radiation due to differences in energy absorption coefficient and specific heat.

the lock-in amplifier. A deviation of the bridge calibration factor has only a small influence in the measured resistance change.

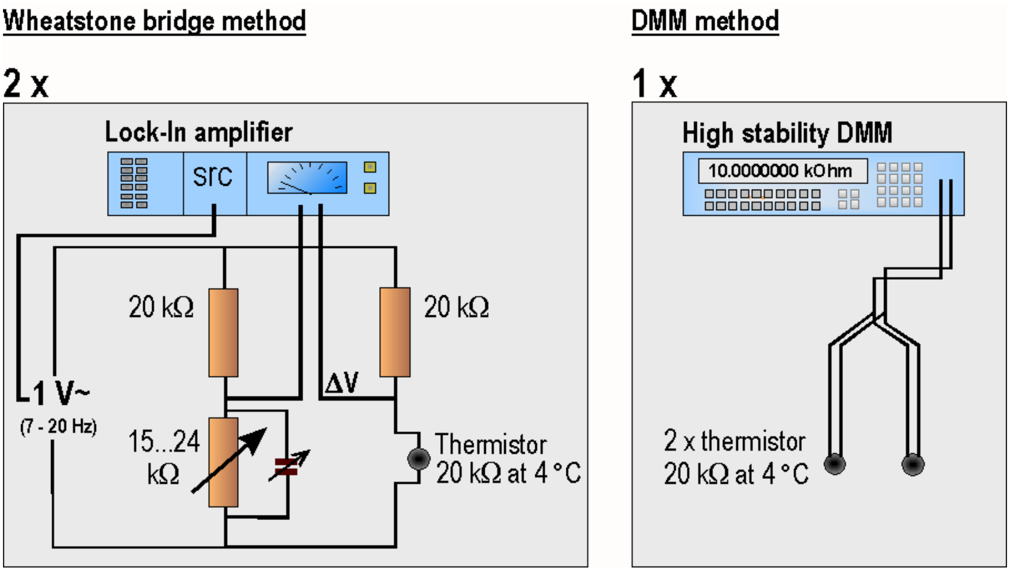

Figure 1. Simplified electrical scheme of the Wheatstone bridge method and the DMM method.

Accurate determination of the bridge calibration factor is not possible, because the calibration factor is dependent on the bridge frequency. It's value is only valid when impedances in opposite arms are closely matched and when the unbalance of the bridge is small.

Due to the small signal generated in a water calorimetry the bridge cannot be re-balanced during irradiation. This means that a deviation in the bridge calibration factor directly enters into the measured resistance and the lock-in amplifier is than used as a voltmeter. Increasing the signal by applying longer drift times is not a solution due to excess heat and temperature drifts in the calorimeter phantom.

In addition, the Wheatstone bridges and lock-in amplifiers are very sensitive to electrical noise, especially in non-standard environments like radiotherapy clinics.

3. DMM method

The above problems led to a new approach for processing the signal for our water calorimeter. This measurement method had to be frequency independent, insensitive to electrical noise, accurate, stable and sensitive enough to perform traceable measurements of small resistance changes in different experimental environments. The solution was found in the use of a high precision, highly stable DMM.

With the new system, two parallel connected 20 kOhm thermistors are used. Their resistance change is measured with an Agilent 3458A high stability DMM. This DMM has a display resolution of 0,001 Ohm and is capable of producing more digits when readout by a remote computer.

The 10 kOhm scale has been calibrated at the Electrical Standards laboratory of NMi. In order to assure that the measured small resistance changes[2] between the calibration points are in fact traceable, the linearity of the 10 kOhm scale has been verified. However, direct

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[2] The resistance change is approximately 0,1 Ohm·Gy^{-1}.

calibration against resistance standards with such resolution is not possible. Therefore the linearity of the 10 kOhm scale test voltage has been measured, which is the 1 V scale. The maximum deviation of the linearity is a measure for the non-statistical (type B) uncertainty in the resistance change and turns out to be better than 300 µOhm. For a 2 Gy irradiation in ^{60}Co gamma radiation this results in an uncertainty contribution of 0,15 %.

Other advantages using a high precision DMM are:

- Excellent electrical characteristics with respect to noise in radiotherapy clinics (see Figure 2).
- Less time consuming compared to the Wheatstone bridge approach because no bridge calibrations are needed.
- The DMM method is easy and straightforward.
- No correction for self-heating of the thermistors is needed because they are calibrated in combination with the DMM as one system.
- The system is compact, easy to transport and easy to install on location.

4. Conclusions

In order to measure small resistance changes in the NMi water calorimeter the Wheatstone bridge method, as used with our graphite calorimeter is not suited. The main cause for arising problems is a deviation in the bridge calibration factor, which enters directly the measured resistance change. Another problem that arose was the sensitivity of the system to electrical noise in non-standard environments.

The DMM method provides accurate and traceable measurements for small resistance changes. The total non-statistical uncertainty contribution is 0,15 % for a 2 Gy irradiation.

The new method is straight forward, insensitive for electrical noise, compact and easy to operate at different locations.

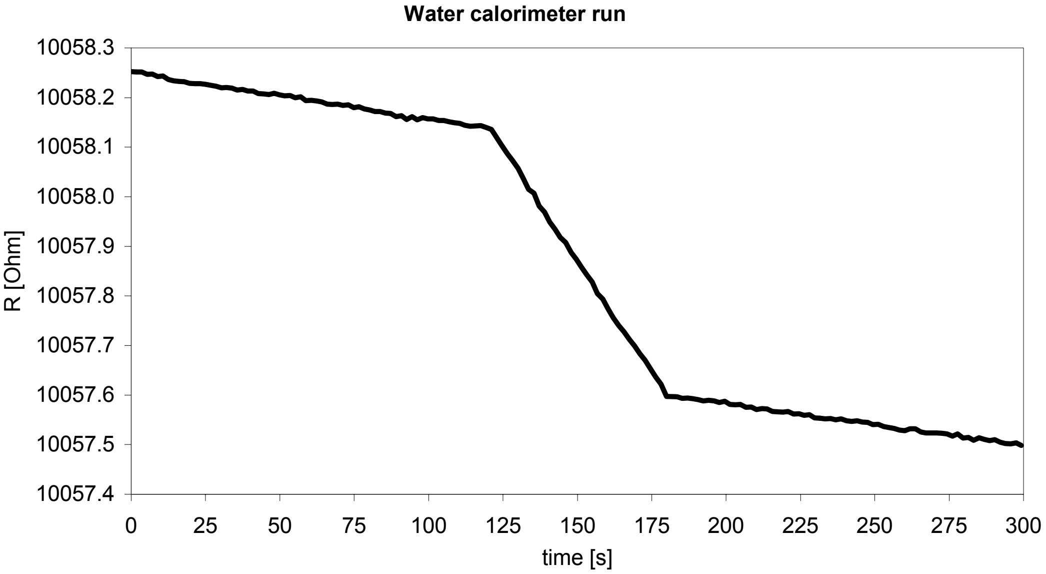

Figure 2. A water calorimeter run in the Elekta SL15 10 MV clinical accelerator beam at the Academic Medical Center, Amsterdam.

References

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[3] Pieksma, M. et al, *Measurement of* k_Q *beam quality correction factors for the NE2611A chamber in high-energy photon beams using the NMi water calorimeter*, IAEA-CN-96-7 (2002).