The Status and Future of Johnson Noise Thermometry

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Abstract — Johnson noise thermometers infer the thermodynamic temperature through measuring the thermally induced electronic fluctuations that occur in all electrical conductors. As a purely electronic approach, Johnson noise thermometry offers an appealing alternative to other forms of primary thermometry and has attracted increasing interest. However, because the noise signal is extremely small, random, and distributed over very wide bandwidths, a number of technological breakthroughs have been required to enable measurements with accuracies comparable to the other primary methods. Over the last few years, Johnson noise thermometry has revealed its potential by contributing to recent measurements of the Boltzmann constant with relative uncertainties of 0.0004%. It is also useful at high temperatures with relative uncertainties of 0.004% demonstrated up to 800 K, and could be competitive with acoustic and radiation thermometry in the difficult temperature range of 600 K to 1000 K.

This presentation will review the current status of Johnson noise thermometry and its prospects, for both metrological measurements and practical implementations and its application in industry. We will begin with the foundations of Johnson noise thermometry and the key breakthroughs leading to the modern metrological noise thermometers: the cross correlator, fast analogue-to-digital converters and frequency domain processing, and especially the quantum-accurate pseudo-random noise source. We will then review the current and emerging metrological applications, including the recent Boltzmann constant determination and the implications of the new kelvin definition. Finally, we will consider future prospects including the possibilities for increased adoption of noise thermometry in industry.

Keywords (Index Terms) — Boltzmann constant, Johnson noise, Josephson voltage standard, noise thermometry.