

Signal Processing Method for Johnson Noise Thermometry

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가
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CPSD(Cross Power Spectral Density)

Abstract

The development of Johnson Noise Thermometry requires a high sensitive preamplifier circuit to pick up the temperature-related noise on the sensing element. However, the random noise generated in this amplification circuit causes a significant erroneous influence to the measurement. This paper describes signal processing mechanism of the Johnson Noise Thermometry system which is underway of development in collaboration between KAERI and ORNL. It adopts two identical amplifier channels and utilizes a digital signal processing technique to remove the independent noise of each channel. The CPSD(Cross Power Spectral Density) function is used to cancel the independent noises and the differentiation of narrow or single frequency peak from the CPSD data separates the common mode electromagnetic interference noise.

1.

가 (conduction electron)
(statistical random motion)

[1].

(zero) 가 H, Nyquist J. B. Johnson [3]. 가

[1-7].

$$e_n^2 = \frac{4hfR}{e^{hf/kT} - 1} \quad [V^2 / Hz] \quad \text{-----(1)}$$

h (6.626 x 10⁻³⁴ [Joule-sec], k (1.68 x 10⁻²³ [Joule/K], f
 , R , T (1) 100°K 가
 1GHz hf/kT << 1 (1)

$$e_n^2 = \frac{4hfR}{e^{hf/kT} - 1} = 4hfR / (1 + \frac{hf}{kT} + \frac{1}{2}(\frac{hf}{kT})^2 \dots - 1) \quad [V^2 / Hz] \quad \text{----- (2)}$$

$$\approx 4hfR / (\frac{hf}{kT}) = 4kTR \quad [V^2 / Hz]$$

가 .

$$i_n^2 = 4kT \frac{1}{R} \quad [A^2 / Hz] \quad \text{----- (3)}$$

(2) (3) (Power) (4)

$$p_n = 4kT \quad [w / Hz] \quad \text{----- (4)}$$

(2) - (4) 3 (, ,) 가
 가 T (e_n²)

2.

RTD(Resistance Temperature Detector) 1

. RTD

가

가

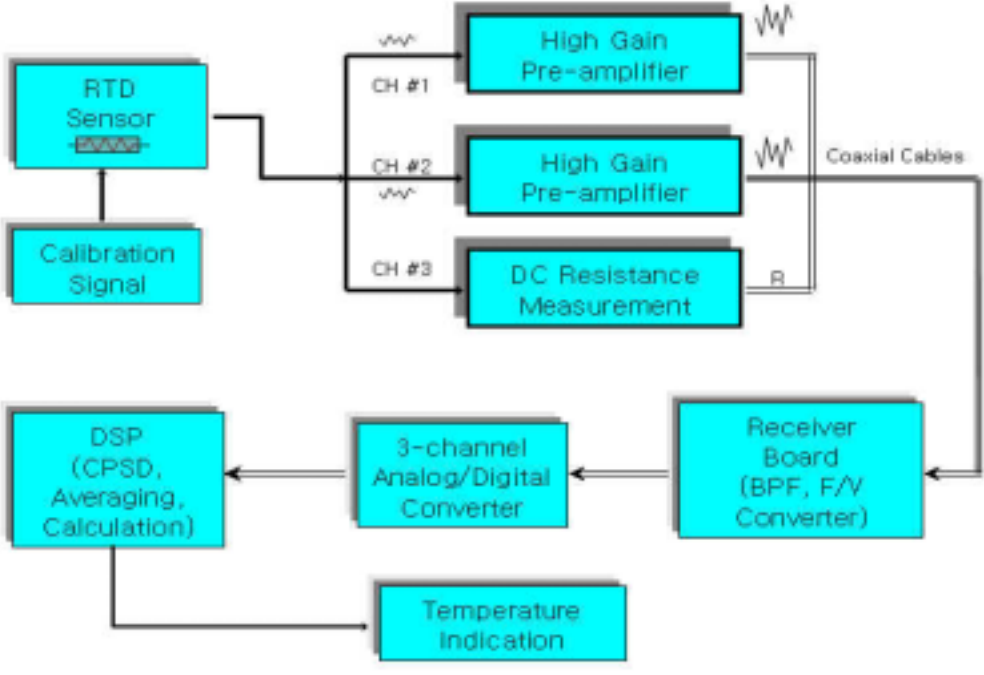
(Pre-Amplifier) 가

Cross Correlation Function

Cross Correlation

Cross Power Spectral Density(CPSD)

Multiplication) (DFT: Digital Fourier Transform) (Conjugate
 CPSD CPSD
 R,



1.

3. Instrumentation Head

1 RTD (Pre-Amplifier), DC Resistance Measurement , Instrument Head .
 가 .
 RTD .
 RTD (DC Resistance) 100dB(10000) .
 (current source) 가 RTD .
 가 .
 Frequency Modulation) 가 . 0° C 100Ohm 25kHz (FM :
 ± 0.5Vpp 가 .
 가 .
 (Receiver Board) .
 Calibration . Calibration (Sweep)

가 Instrument Calibration DC

FM

4. (Receiver Board and Digital Signal Processing Module)

가 100kHz (BPF: Band
 Pass Filter) 2MHz
 (FM) 200kHz – 1.5MHz
 DC PLL(Phase Locked Loop)
 DC Voltage (Band
 Pass Filter) DC - (Frequency-Voltage Conversion)

3 CPSD 1.5 MHz 3-4 MHz Sampling Rate
 A/D(Anlog-to-Digital)

(FFT : Fast Fourier Transform)

CPSD CPSD
 Power Spectrum

CPSD Calibration
 EMI(Electromagnetic Interference) 가
 CPSD

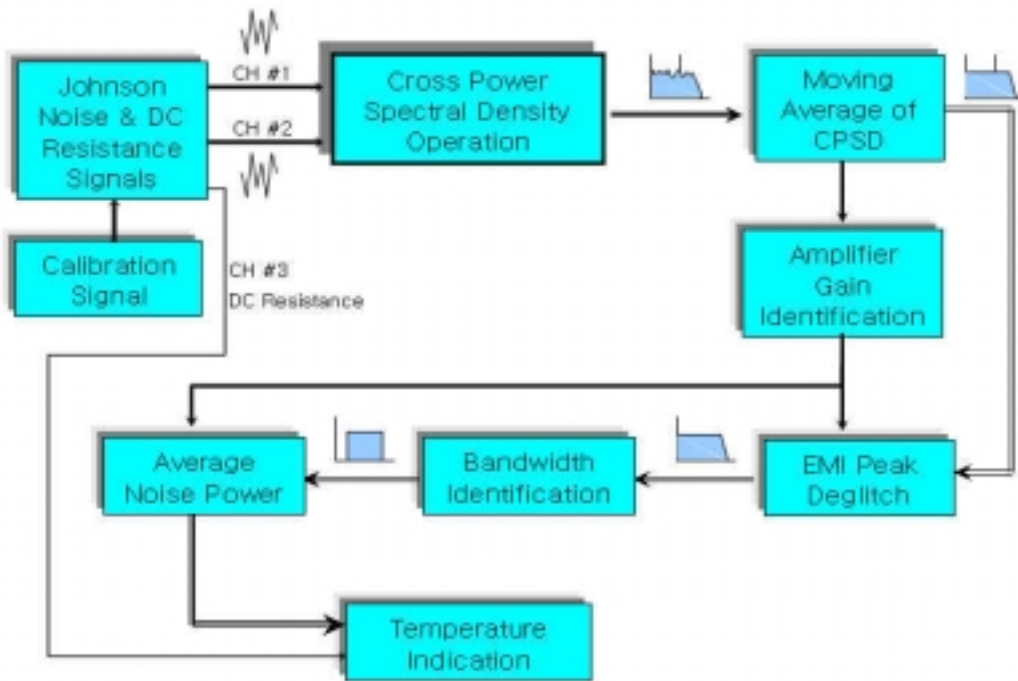
(stationary) CPSD Calibration Sweeping 가 CPSD

CPSD Calibration Power
 가 Peak
 Calibration Peak 가

5 EMI EMI Peak EMI
 Deglitch CPSD
 (2) 3 DC-Resistance

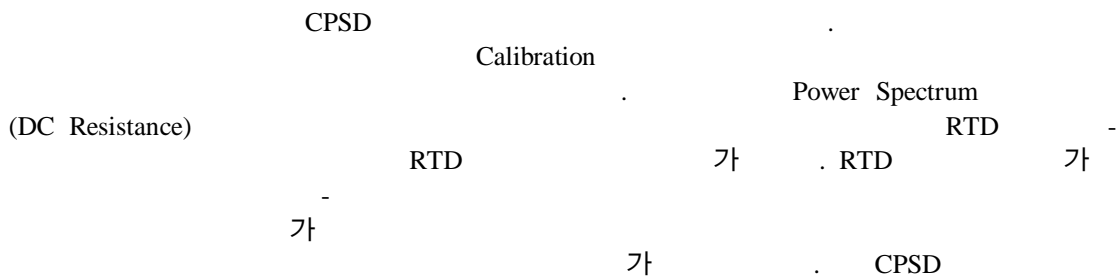
RTD - RTD - RTD (R-T)

2 Block Diagram



2.

5.



Acknowledgement

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- [4] Blalock T.V. and Shepard R.L., "A Decade of Progress in High-Temperature Johnson Noise Thermometry," Temperature, Its Measurement and Control in Science and Industry, Vol.5, Part2, American Institute of Physics, Washington, D.C., pp. 1219-1237, 1982.
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- [6] Borkowski C.J. and Blalock T.V., "A New Method of Johnson Noise Thermometry," Rev. Sci., Instrum., 45(2), 151, 1974.
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