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Bolometer Detector Modeling and its Performance Indexes

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ABSTRACT

Bolometer detector is one of thermal detectors. In this research the essential concepts and parameters are included which cover the main types of bolometer detectors. But the actual values of parameters used here in simulation are adopted from [7] for semiconductor bolometer. This detector operates for all optical wavelengths of different sources. From analysis and results obtained, it is shown that minimum and maximum values of specific Detectivity D^* for cryogenic temperatures from 0.5 K to 10 K are 0.25×10 $^{/2}W^{-1}$ and 5×10 $^{1/2}$, respectively and the values between them when the incident radiation frequency is 100 Hz.. It is seen that for frequency greater than 1Hz, the specific Detectivity increases rapidly which means that the bolometer detector will respond for high frequencies in a manner more speed than that of low frequencies. It is found that as the value of τ_{th} is increased, the temperature change in detector sensor is decreased. That is decreasing τ_{th} enhance the performance of bolometer detector. It is found that the responsivity of this detector follow its output voltage which in turn follow the bolometer temperature change.

Keywords: Bolometer detector, thermal time constant, NEP, Voltage response, responsivity, or Detectivity.

نمذجة كاشف البولوميتر ومؤشرات اداءه

الخلاصة

ان كاشف البولوميتر هو أحد انواع الكواشف الحرارية. في هذا البحث تم تضمين المفاهيم والمعلمات الاساسية التي تغطي الأنواع المختلفة للكواشف البولوميترية. ولكن المتغيرات الفعلية والتي تم استخدامها هنا في المحاكاة هي مقتبسة من المصدررقم 7 للبولوميتر شبه الموصل. يعمل هذا الكاشف على جميع الأطوال الموجية البصرية ذات المصادر المختلفة. وتبين من النتائج التي تم الحصول عليها ان قيم الكشفية النوعية D^* للدرجات الحرارية المنخفضة 0.5 كلفن و 10 كلفن هي 0.25×10 $^{1/2}$ و $5 \times 10^4 cmHz^{1/2}W^{-1}$ على التوالي والقيم الواقعة بينهماعندما يكون تردد الأشعاع الساقط هو 100هرتز . ولقد تبين أن الكشفية النوعية تزداد على نحو سريع لترددات الأشعاع الساقط التي تزيد عن 1 هيرتز والتي تعني أن استجابة كاشف البولوميتر ستزداد بزيادة تردد الأشعاع الساقط. وتبين أنه بزيادة قيمة الثابت الزمني الحراري للكاشف فأن التغير الحاصل في درجة حرارة متحسس الكاشف سوف تقل. وهذا يعني ان تقليل الثابت الزمني الحراري سيحسن من أداء كاشف البولوميتر. لقد وجد أن استجابية هذا الكاشف تتبع فولتية خرجه التي بدورها تتبع التغير الحاصل في درجة حرارة البولوميتر.

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INTRODUCTION

The “bolometer” name derived from a composite word of Greek origin, namely *bole* (ray, beam) and *metron* (meter, measure) [1, 2].

A bolometer is a very sensitive thermometric instrument used for the detection and measurement of radiant energy which can cause a change of temperature of the sensor [2, 3]. Bolometer principle such as any other thermal radiation detector based on the absorption of electromagnetic radiation energy and thus increases its material temperature. There are several temperature sensing principles which called thermal effects upon which several known types of thermal detectors such as bolometer detector based on temperature coefficient of resistance; pyroelectric detector based on pyroelectric effect exhibited by temperature sensitive ferroelectric crystals that show spontaneous polarization characterized by a pyroelectric coefficient; thermoelectric detector based on the principle of the thermocouple (Seebeck effect); pneumatic (Golay cell) detector based on that the absorption of the incident radiation within specified chamber causes pressure fluctuations which in turn cause the curvature of its flexible mirror to change[1, 4, 5, 6].

A bolometer is a detector constructed from an absorbing material of incoming radiation having a resistance of a large temperature coefficient. Photons incident on the absorber raise its temperature, causing a sensitive thermometer attached to it to change resistance. The resultant temperature rise is measured as a change in voltage or current in the readout circuit. The bolometer detector is named according to its active component, e.g. thermistor bolometer, semiconductor bolometer, superconductor bolometer. A bolometer is a radiant power detecting device which measures the change in resistance of a sensing material due to the heating effect of absorbed radiation.

TEMPERATURE COEFFICIENT OF RESISTANCE (TCR)

It is became known that some materials can absorb the incoming electromagnetic radiation. The absorption process results in increasing the kinetic energy of free electrons. Collisions of free electrons with atoms in the materials cause lattice vibrations which are observed as a change in temperature. There are typical thermometer materials such as metals and doped semiconductors. The resistance R for such absorbing material changes significantly for a small change in temperature. This can be represented by exponential temperature variation of resistance [4]

$$R(\mathrm{T}) = R_0 \exp\left[\left(\frac{\mathrm{T}_g}{\mathrm{T}}\right)^n\right] = R_0 \exp\left[\mathrm{T}_g^n\, \mathrm{T}^{-n}\right] \ldots (1)$$

Where T_g (band gap temperature) and n are parameters of the conducting material, and R_0 is a thermal model parameter represents a characteristic resistance that depends on both the material and the device geometry. T is the temperature of bolometer resistor. For normal semiconductors $n = 1$, but the form of impurity conduction found in bolometer material is better characterized by $n = 0.5$ and typical values for T_g^n are in the range $20 - 30\,K^{1/2}$ [4].

Differentiating (1) with respect to temperature, we obtain

$$\frac{dR}{dT} = -nT_g^n\, T^{-n-1}\, R_0 \exp\left[T_g^n\, T^{-n}\right] = -n\,R\,T_g^n\, T^{-(n+1)} \quad \ldots(2)$$

From which we find that

$$\frac{1}{R}\frac{dR}{dT} = -n\,T_g^n\,T^{-(n+1)} \qquad \ldots(3)$$

The Left Hand Side of (3) constitute an important parameter called the temperature coefficient of resistance (TCR) and is denoted by a , i.e.,

$$a = \frac{1}{R}\frac{dR}{dT} \quad [K^{-1}] \quad \ldots(4)$$

In metals a is positive, while in semiconductors it is negative [7].

BOLOMETER DETECTOR MODEL

Thermal parameters of Bolometer

Regardless of the geometry, an ideal bolometer can be modeled to be such as any thermal detector to consist of a thermally isolated infrared absorber (membrane) with an embedded resistor which should have a high value of TCR. The resistors are typically made of metals such as titanium (Ti), nickel, or platinum, or semiconductors such as vanadium oxide, germanium, or silicon. The incident IR radiation absorbed by the membrane warms up the embedded resistor and as a result, its resistance is changed [8].

The absorbing element is of heat capacity $C_{th}[J/K]$ at a temperature $T + \Delta T$ which is connected to a cold bath (heat sink) with temperature T through a low thermal conductance $G_{th}[W/K]$. In this model the losses through radiation is not taken into account.

Figure 1 shows the main parameters and parts that constitute the bolometer detector. $P_{in}(t)$ is the radiation flux, $I(t)$ is the bias current which assumed to be a periodic function and V_{out} is the bolometer output voltage. Thus, the system has two inputs, P_{in} and I, and one output, V_{out}. The change in resistance is detected as a change the voltage V_{out} when applying a current I to the bolometer in series with a reference load R_L. The resistance of the load resistor is normally designed to be much higher than the resistance of the bolometer R over its entire operating range. This is to keep the current passing through the bolometer at a stable level so that the power dissipated in the bolometer by the resistance thermometer stays somewhat constant.

Ideally, the bolometer will have a large change in resistivity for a small change in temperature $\Delta \mathrm{T}$. The thermal conductivity of the thermal link also varies with temperature follows a power law [9]:,

$$G_{th}(\mathrm{T}) = G\left(\frac{\mathrm{T}+\Delta\mathrm{T}}{\mathrm{T}}\right)^{b} \qquad \dots (5)$$

which leads to the following expression of the power through the link[9]

$$\mathrm{P}_{link} = \frac{G}{(b+1)\mathrm{T}^{b}}\left((\mathrm{T}+\Delta\mathrm{T})^{b+1} - \mathrm{T}^{b+1}\right) \qquad \dots. (6)$$

where T and $(\mathrm{T}+\Delta\mathrm{T})$ are the bath and the bolometer temperatures, respectively, G is the static thermal conductance at temperature $\mathrm{T} = \mathrm{T}_{reference}$ and b is a constant.

For a given bolometer, the set of parameters { $R_{\mathbf{0}}, \mathrm{T}_{g}, G, b$ } are determined experimentally.

A bolometer as a thermal detector can be modeled as a first-order differential RC low pass filter with a thermal time constant $t_{th} = C_{th}/G_{th}$. If the bolometer temperature response is $\Delta\mathrm{T}$, to the thermal radiation P_{in}, the self-heating P_{sh}: "due to Joule effect in which an electric current I is transformed irreversibly into heat P according to $\mathrm{P} = \mathrm{I}^{2}R$, where R is the electrical resistance of the bolometer" and background radiant energy. The differential heat balance equation (thermo-equilibrium) for the bolometer behavior is described as [10, 11, 12]

$$C_{th}\frac{d\Delta\mathrm{T}}{dt} + G_{th}\Delta\mathrm{T} = \mathrm{P}_{sh} + \mathrm{P}_{bg} + h\mathrm{P}_{in} \qquad \dots.. (7)$$

Ignoring (in this model) the terms related to self heating and background radiant powers, the bolometer equation reduced to the general thermal radiation detector [10, 11, 13]

$$C_{th}\frac{d\Delta\mathrm{T}}{dt} + G_{th}\Delta\mathrm{T} = h\,\mathrm{P}_{in} \qquad \dots (8)$$

This approach has been taken in much of the literature and represents a simplified model in which the radiation conductance G_{rad} is often neglected, however it should be noted that if the thermal conductance to the substrate G_{th} approaches the value of the radiation conductance G_{rad} , then both should be taken into account.

when the bias current is a DC signal and the flux radiation is a sinusoidal of the form [12]

$$\mathrm{P}_{in}(t) = \mathrm{P}_w e^{jwt} \qquad \text{... (9)}$$

where P_w is the amplitude of the incident radiation, the output response of the bolometer is the solution of eq.(8) which represents the temperature rise in the bolometer due to these inputs and given by [12, 13]

$$\Delta\mathrm{T}(t) = e^{-t/t_{th}}\,\Delta\mathrm{T}(0) + \frac{h}{G_{th}}\left(\frac{1}{1 + jwt_{th}}\right)\mathrm{P}_w e^{jwt} \qquad \text{… (10)}$$

The response consists of two terms: a transient term which is independent of the input frequency, and a sinusoidal steady state term. If the bolometer is stable, the transient term decays exponentially to zero and its effect on the over all response can be ignored after a short period of time. Thus, the rise in the bolometer temperature at steady state is only due to the second term which is [12, 13]

$$\Delta\mathrm{T}(\infty) = \frac{h\,\mathrm{P}_w}{G_{th}(1 + w^2 t_{th}^2)^{1/2}} \qquad \text{…. (11)}$$

It is clear from eq.(11) that to achieve a high $\Delta\mathrm{T}$, the thermal conductance G_{th} of the link between the detector and the heat sink should be as small as possible to obtain a small thermal conduction between the bolometer and its surroundings, the bolometer legs are long, have a small cross-sectional area and consist of materials with a low thermal conductivity. Thermal conduction through the bolometer legs can be as low as $3.5\times10^{-8} W/K$ [1]. The thermal time constant $t_{th} = C_{th}/G_{th} = C_{th}R_{th}$ determines the speed of response of bolometer detector. If the detector has a large C_{th} value, its temporal response will be slow and it is obvious that if one wants to increase $\Delta\mathrm{T}$ by decreasing G_{th} while keeping t_{th} unchanged, C_{th} has to be decreased by the same amount as G_{th} .

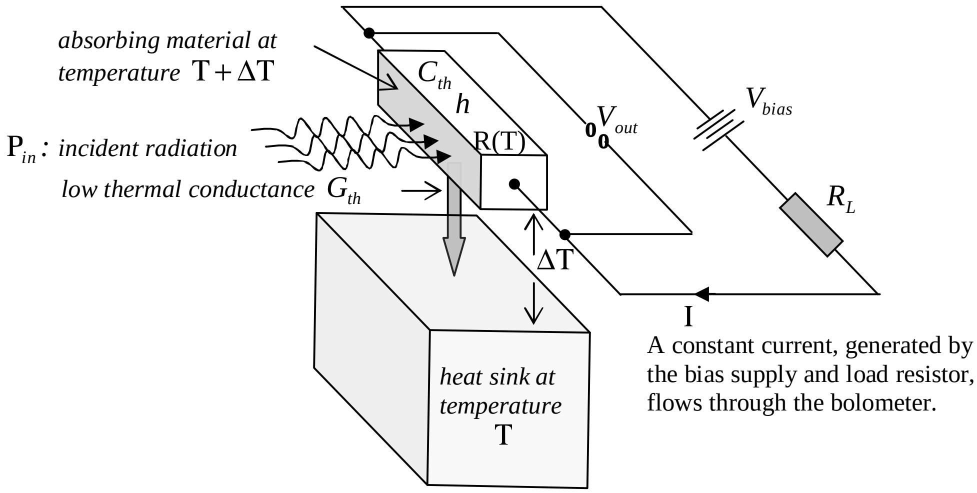

Figure (1): Schematic electrical and thermal circuit diagram of a simplified bolometer detector principle. The bolometer with heat capacity C_{th}, absorptivity (optical absorptance) h and resistance R (which is a function of temperature) is connected to a thermal bath maintained at constant temperature T through a weak link of thermal conductance G_{th}. The absorbed power of incident radiation, hP_{in}, changes the temperature and thus the resistance of the bolometer. The change of the bolometer resistance is detected by measuring in the applied bias voltage across the bolometer. In current bias condition, $R_L >> R(T)$. The V_{out} voltage across the bolometer is measured through a low noise voltage amplifier (generally, this will be a cryogenic device to minimize thermal noise in the circuit).

Electrical Parameters of Bolometer

Bolometers use the temperature dependency of the electric resistance. Resistive bolometers are thermal detectors whose electrical resistance R changes with the absorbed irradiance (heat of thermal radiation). From (4) the relation between a temperature change ΔT and a resistance change ΔR is

$$dR = a\ R\,dT \qquad \text{... (12)}$$

From which, we can write

$$\Delta R = a\ R\,\Delta T \qquad \text{... (13)}$$

The change in resistance leads to a changed signal voltage. Hence, the voltage change across the bolometer element is

$$\Delta V_{out} = \mathrm{I}\Delta R \quad = \mathrm{I}a\ R\Delta \mathrm{T} \qquad \text{... (14)}$$

Where I is the current pass through the bolometer. Hence, the amplitude of the steady state change in the bolometer open circuit output voltage due to the change in temperature specified by (11) is

$$\Delta V_{out} = \frac{\mathrm{I}a\ Rh\,\mathrm{P}_w}{G_{th}\left(1+w^2t_{th}^2\right)^{1/2}} \qquad \text{... (15)}$$

Equation 15 summarizes the main design features of bolometer detectors. It is clear that bolometer voltage is a function of bias current and radiant power loading. Some of the most important bolometer design parameters are a low thermal conductance between the bolometer and its surrounding, a high absorption of thermal (infrared) radiation, a bolometer temperature sensing material with a high TCR, and a sufficiently low bolometer thermal time constant.

BOLOMETER DETECTOR PERFORMANCE INDICES

It is important to introduce essential performance indices that describe how well a detector performs. These indices will be defined in terms of the detector outputs, the radiometric inputs, and other test conditions. It is assumed that they are obtained under standard test conditions; the source temperature is usually taken to be the blackbody radiation at room temperature $\mathrm{T}_S = 300^{\circ}\mathrm{K}$, while the reference bandwidth is taken to be the measurement bandwidth [12].

The main Figures of Merit of a bolometric detector are: noise equivalent power *NEP*, voltage responsivity R_V , specific Detectivity *D** and thermal time constant τ_{th}.

Voltage Responsivity

Let an IR input signal, which is characterized in terms of its irradiance E, be incident upon a detector of cross section area of A. The voltage responsivity R_V of the bolometer or the “system gain” is determined by the ratio of the detector signal (detector output) to the optical power incident on the detector (detector input),

$$R_V = \frac{\Delta V_{out}}{\mathrm{P}_w} = \frac{\Delta V_{out}}{EA} \qquad \text{… (16)}$$

Thus,

$$R_V = \frac{\mathrm{I}a\ Rh}{G_{th}\left(1+w^2t_{th}^2\right)^{1/2}} \qquad \text{... (17)}$$

Hence, the detector system can be represented by introducing the concept of transfer function shown in Figure (2)

$$input = P_w \longrightarrow \boxed{\frac{Ia\ Rh}{G_{th}(1+w^2 t_{th}^2)^{1/2}}} \longrightarrow output = \Delta V_{out}$$

Figure (2): Block diagram representation of bolometer Detector with transfer function.

It is clear from (17) that if $w << 1/t_{th}$, $R_V \propto \frac{1}{G_{th}}$ and if $w >> 1/t_{th}$, $R_V \propto \frac{1}{w C_{th}}$.

Detector Noise Performance Indices

Since the ultimate performance of infrared detectors is limited by noise, it is also important to define certain noise performance indices or figures of merit to reflect this performance.

Noise Equivalent Power (NEP)

The optical input power to the detector that produces a signal-to-noise ratio of unity (S/N=1).

The NEP is one of the most commonly used performance index, relating the sinusoidally modulated radiant power falling upon a detector (input) capable of producing a signal to noise ratio (S/N) of unity. That is the optical power (input) will produce a rms signal voltage (output) equal to the rms noise voltage. Hence for detecting a signal, signal to noise ratio should be greater than unity. So NEP is the minimum detectable radiant flux by the bolometer which calculated by the following expression [7, 12]

$$NEP = \frac{V_n}{R_V \sqrt{\Delta f}} = P_w \left(\frac{V_n}{\Delta V_{out}} \right) \frac{1}{\sqrt{\Delta f}} \qquad \text{…. (18)}$$

where Δf is the measurement bandwidth. In this definition, it is assumed that Δf is small enough so that V_n (noise voltage) is constant over this bandwidth. The units of NEP are $W / Hz^{1/2}$. In general, in a bolometric circuit, a considerable number of noises are present. V_n can be expressed as the quadratic sum of the squares of different voltage noises [7]

$$V_n^2 = V_J^2 + V_{ph}^2 + V_{1/f}^2 \qquad \text{…. (19)}$$

where V_J is Johnson noise voltage, V_{ph} is photon noise voltage, and $V_{1/f}$ is $1/f$ noise voltage. Then

$$V_n = \sqrt{V_J^2 + V_{ph}^2 + V_{1/f}^2} \quad \text{.... (20)}$$

Then from (16), (18), and (20), we obtain

$$NEP = \frac{\mathrm{P}_w \sqrt{V_J^2 + V_{ph}^2 + V_{1/f}^2}}{\Delta V_{out}} \frac{1}{\sqrt{\Delta f}} \quad \text{.... (21)}$$

Detectivity and Specific Detectivity

Detectivity D of a detector is defined as reciprocal value of noise equivalent power NEP. Hence

$$D = \frac{1}{NEP} \quad \text{... (22)}$$

However, most of the parameters used to calculate the NEP depend on the detector area. So in most cases, it is preferable that instead of Detectivity D, *specific Detectivity* D*, which is given as the ratio between square root of detector area and noise equivalent power [7].

$$D^* = \frac{\sqrt{A}}{NEP} = D\sqrt{A} \quad \text{.... (23a)}$$

Thus, Detectivity is the area normalized S/N and its unit is $cm.Hz^{1/2}/W$. According to eq.(18), the specific Detectivity performance index D^* can also be written in the following alternate form

$$D^* = \frac{R_V \sqrt{A\Delta f}}{V_n} = \frac{1}{\mathrm{P}_w}\left(\frac{\Delta V_{out}}{V_n}\right)\sqrt{A\Delta f} \quad \text{... (23b)}$$

Thermal Time Constant

The thermal time constant is an important parameter that determines the speed at which the bolometer response to the incident radiation from any source. Thermal time constant t_{th} is the time required for the detector (any system) output to reach a value $\left(1-\frac{1}{e}\right) \cong 63\%$ of its final steady state value. Bandwidth is related to the thermal time constant by the relation

$$\Delta f = \frac{1}{2p t_{th}} \qquad \ldots (24)$$

If ΔT_{low} is the temperature signal of bolometer at low frequency f_{low}(few Hertz), the signal at higher frequencies for $f \gg f_{low}$ is

$$\Delta T_f = \frac{\Delta T_{low}}{\left(1+(2pft_{th})^2\right)^{1/2}} \qquad \ldots (25)$$

This relation is graphically illustrated in Figure(3). The corner or cut off frequency is the point at which $\Delta T_f = \frac{1}{\sqrt{2}}\Delta T_{low}$.

SIMULATION RESULTS AND DISCUSSION

For the purpose of simulation and discussion of bolometer detector model, it is necessary to use some information related to specified sensing material. Assume that the sensing material of bolometer absorber is the titanium. Its absorptivity is 80% and its thermal conductance is $2.2\times10^{-7} W.K^{-1}$. The thermal time constant is $15\,ms$; its temperature coefficient of resistance TCR is $+0.25\,K^{-1}$, bolometer resistance=$10\,k\Omega$ and assuming that the biasing current is $10\,mA$. It is will be clear that the corner frequency in all plots stays fixed when fixing the value of thermal time constant as shown in Figs. 4, 5, and 6.

Frequency Response of Temperature Change.

Firstly, we start by testing the frequency response of bolometer detector temperature change for the inputs above for the interval 10^{-3} to 10^{3} Hz assuming that the incoming infrared radiation has $5\,mW$ of power. Simulating ΔT against radiation frequency represented by equation 11, figure 3 is obtained which represents the general shape of the change in detector material temperature in micro Kelvin when modulated radiation incident upon thermal radiation detectors. From equation 11 also, using decibel scale of detector temperature change for the same range of frequency, figure 4 is obtained from which the corner frequency is seen clearly at 10 Hz for $t_{th} = 15\,ms$ the same parameters used in Fig. (3) mentioned in section 5.

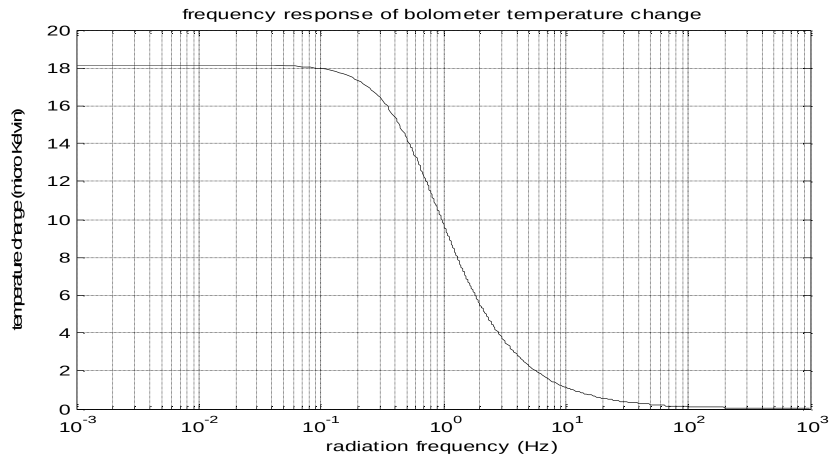

Figure (3): The frequency response of bolometer temperature change. It is difficult here to define the location of cut-off (corner) frequency. See Fig 4 for the same parameters.

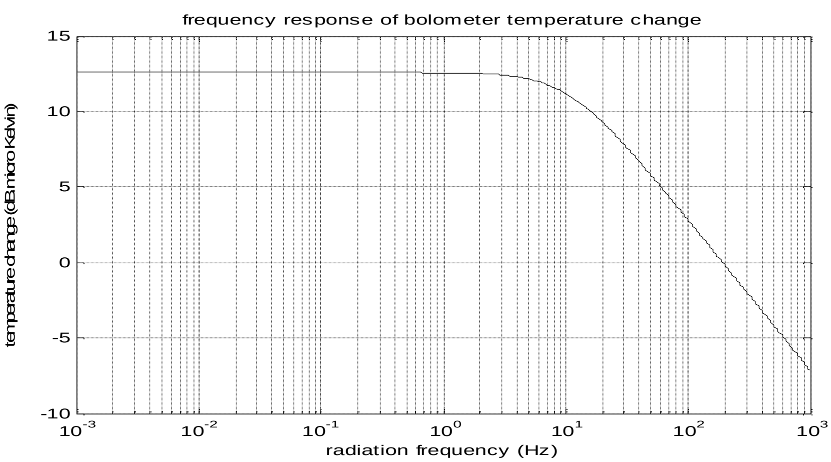

Figure (4): Frequency response of temperature change $\Delta T(w)$ for bolometer detector using decibel scale. As it is expected, the bolometer detector represents a low pass filter its cut-off frequency position related to t_{th} Signal in all thermal detectors is constant versus frequency at low frequencies but begins to decline as a frequency increases. The decline is a function of the thermal time constant which its value here is 15ms (see section 5).

Output Voltage versus Radiation Frequency

The steady state rise in temperature results in the bolometer to rise to its steady state voltage. The output voltage represents the electrical parameter of the bolometer detector. The temperature change causes a change in the voltage drop across the bolometer. Fig. 5 is obtained from the application of equation 15 for the same parameters mentioned in section 5 and subsection 5.1as depicted in Figure (5).

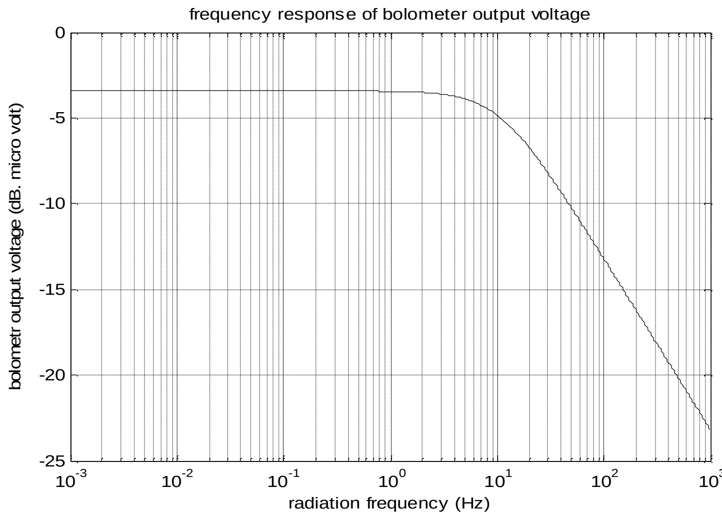

Figure (5): Frequency response of bolometer detector output voltage.

Bolometer Responsivity (Bolometer Gain)

The responsivity of bolometer detector is defined in equations (16 and17), which is the output voltage of system over the magnitude of the incoming modulated radiation power. It is expected that the responsivity of bolometer detector will follow its output voltage.

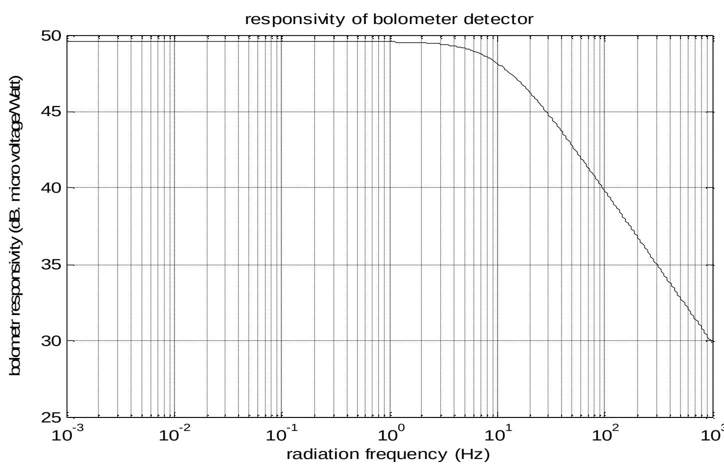

Figure (6): A plot of bolometer responsivity with frequency of incoming radiation.

Thermal Time Constant

Figures (7 & 8) show 15 frequency response signals for different values of τ_{th}. Signal number 1 in Fig. (8) represents the initial value (256 msec) of τ_{th} which follow signal number 1 in Fig. (7) and so on for the rest signals of 2 through 15, thermal time constants used here in Figures 7 and 8 as sequenced are: 128msec, 64msec, 32msec, 16msec, 8msec, 4msec, 2msec, 1msec, 0.5msec, 0.25msec, 0.125msec, 0.0625msec, 0.03125msec, and 0.015625msec respectively which shown as indicated by numbers in Figures (7 and 8). Figure 9 represents the relation between the change in temperature of bolometer detector and thermal time constant in which the frequency of incident radiation is fixed at 1 Hz. It is clear that as the value of τ_{th} is increased, the temperature change is decreased. That is decreasing τ_{th} enhance the performance of bolometer detector.

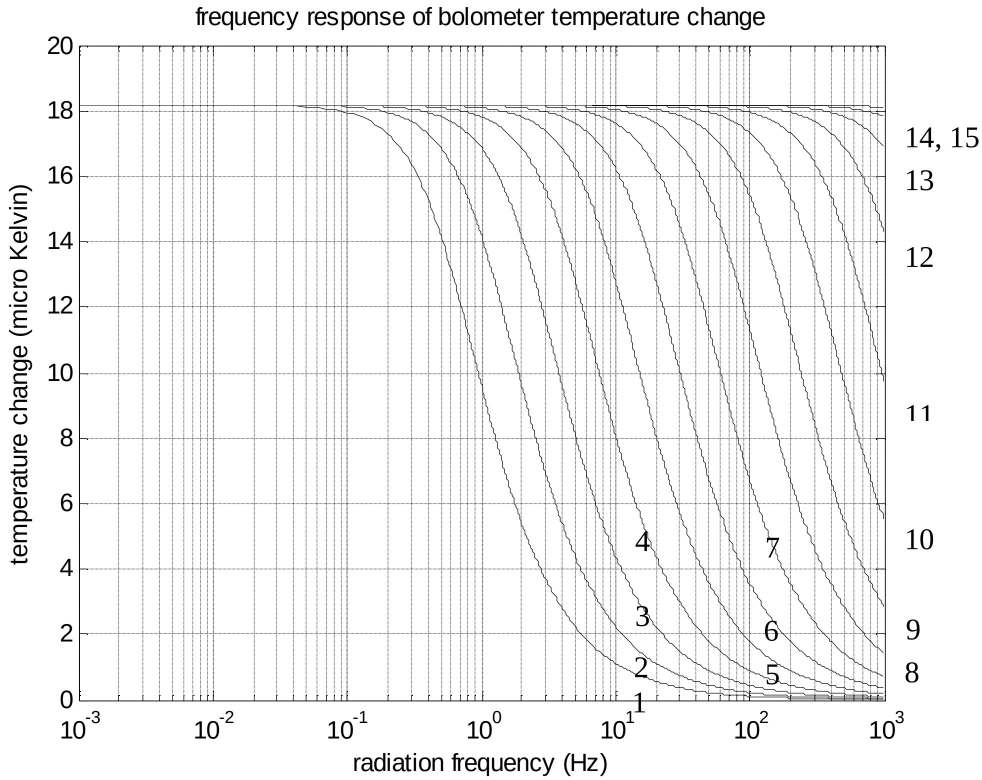

Figure (7): 15 signals represent the frequency response of bolometer detector temperature change for different values of thermal time constant.

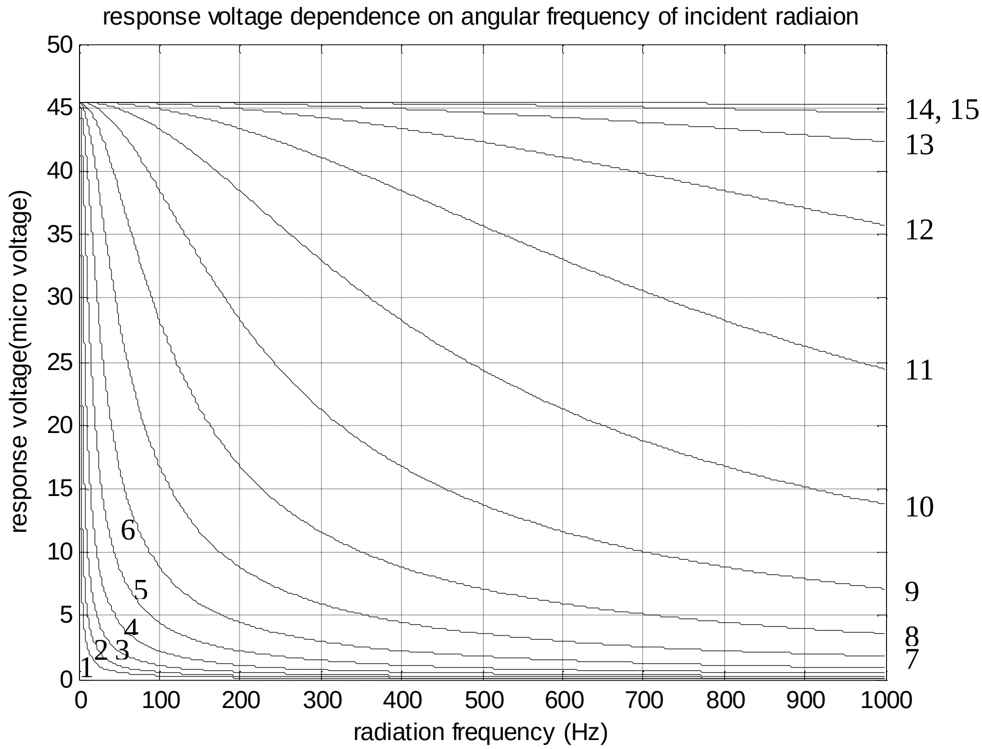

Figure (8): Response voltage, from left to right large to small values of thermal time constant. There are 15 responses for 15 different values of τ_{th}. It is clear from this figure and figure 7 that the response voltage follow temperature changes.

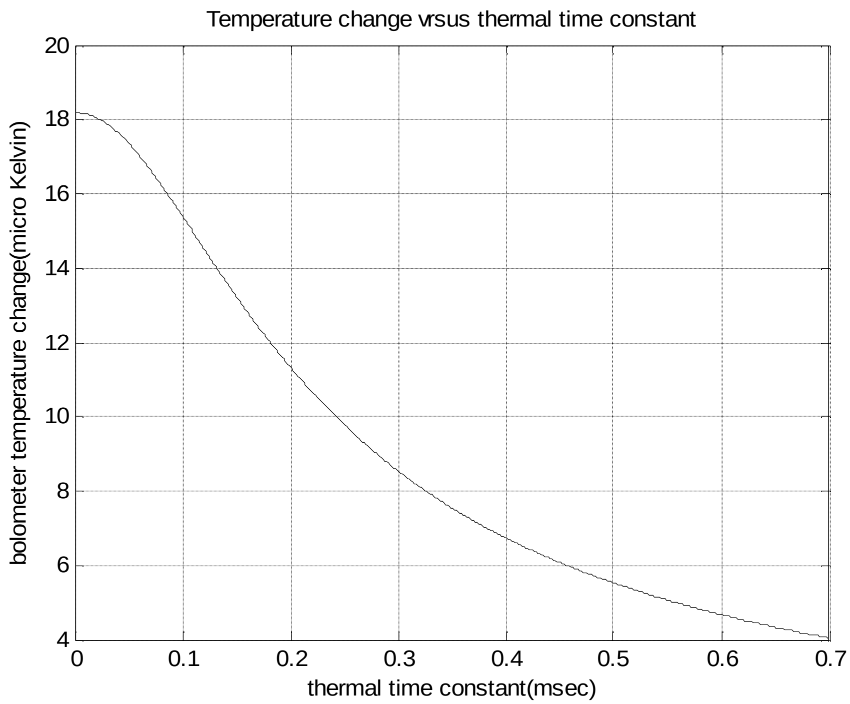

Figure (9): Another representation of the relation between temperature changes of bolometer detector and thermal time constant for radiation frequency of 1Hz. The reverse relation is clear between them.

Bolometer NEP

Here the following parameters which used to simulate the bolometer detector performance represent real values adopted from [7] for semiconductor material, germanium are : bolometer sensor resistance $R = 10\,k\Omega$, bias current $I = 20\,mA$, input power of incoming radiation $P_w = 4\,mW$, modulation frequency $f_m = 10\,kHz$, thermal conductance $G_{th} = 10^{-7}W/K$, thermal capacitance $C_{th} = 10^{-9}J/K$ and bolometer material quantum efficiency $h = 0.8$. For these inputs it is found that the increase in bolometer sensor material is $\Delta T = 0.0509\,K$ which estimated by applying equation 11. Using this value of ΔT, it is found that the value of the bolometer output voltage is 0.0025 volt and the responsivity is nearly 635 V/W. According to the definition of Noise Equivalent Power, the ratio $V_n / \Delta V_{out}$ in equation (18) is assumed to be unity, the NEP is $4\times10^{-6}W/Hz^{1/2}$. It is possible to explain the relation between NEP of the bolometer and temperature change by plotting NEP versus temperature. The NEP of bolometer was analysed for the case of cryogenic temperatures, 0.1 K to 5.5 K. as shown in Fig. 10, an increase in temperature of sensing material results in thermal fluctuations across the bolometer which in turn requires an increase in NEP to compensate these fluctuations. Fig.11 shows that increasing the modulation of incident radiation will results in decreasing the NEP for the same specified interval of temperature.

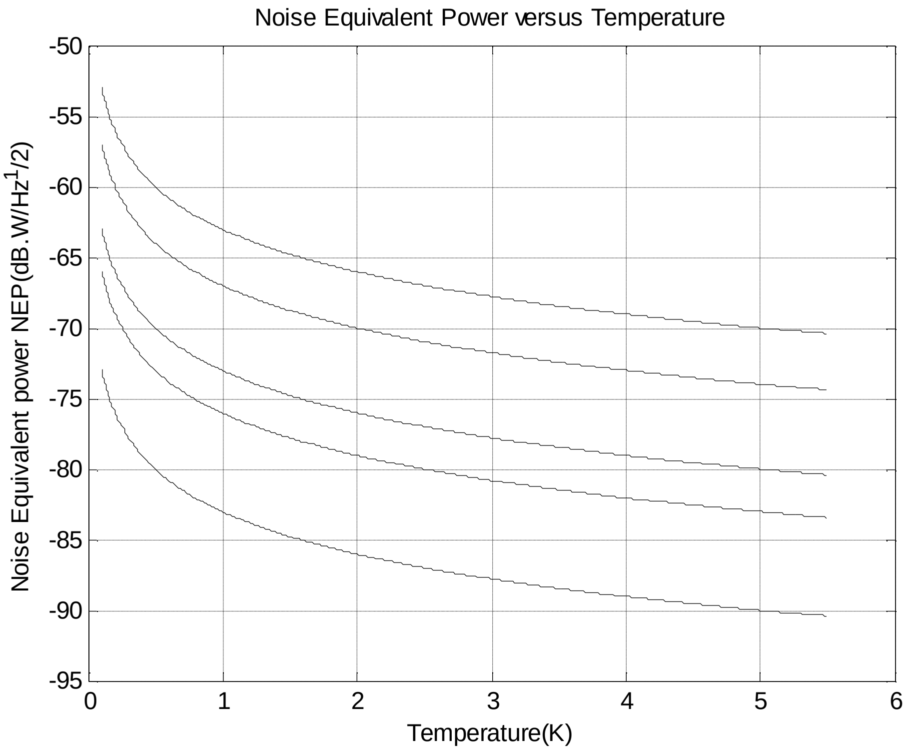

Figure (10): Noise Equivalent Power change with specific interval of cryogenic temperature for bolometer detector using decibel scale. From below the powers of incident radiation are: 0.1µW, 0.5 µW, 1µW, 4µW, and 10µW respectively.

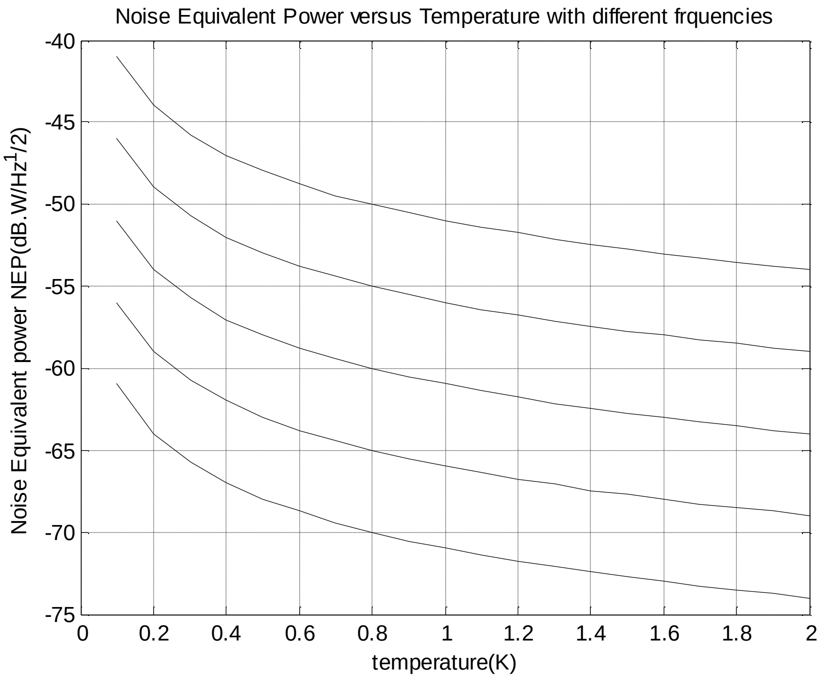

Figure (11): Another shape of NEP versus Temperature with different values of frequency of incoming radiation using decibel scale. From above to down the frequencies are 1Hz, 10 Hz, 100Hz, 1 kHz and 10 kHz respectively.

Bolometer Detectivity

In this section frequency and temperature dependences of the specific Detectivity of bolometer were introduced as performance parameters. In the case of temperature dependence of the specific Detectivity, the frequency was fixed at 1 Hz and an interval of cryogenic temperature from 0.5 to 10 K as an input parameter to bolometer detector. Here the analysing is based on the assume that the sensitive layer area of 10^{-6} cm^2. From analysis made and results obtained, it is shown that maximum and minimum values of specific Detectivity D^* for cryogenic temperatures from 0.5 K to 10 K are:
$0.25 \times 10^4 cmHz^{1/2}W^{-1} to 5 \times 10^4 cmHz^{1/2}W^{-1}$for1Hz, $1 \times 10^4 cmHz^{1/2}W^{-1}$ to $16 \times 10^4 cmHz^{1/2}W^{-1}$for 10 Hz, $0.25 \times 10^5 cmHz^{1/2}W^{-1}$to
$5 \times 10^5 cmHz^{1/2}W^{-1}$for100Hz,and$1 \times 10^5 cmHz^{1/2}W^{-1}$ to$16 \times 10^5 cmHz^{1/2}W^{-1}$ for 1kHz, respectively as shown in Figure 12.

Figure (13) represents another representation of bolometer specific Detectivity. Here the temperature regarded to be fixed meanwhile the frequency of incident radiation is a vector start at 0.001 Hz and end at 1000Hz. It is, clearly, seen that for frequency greater than 1Hz, the specific Detectivity is increase rapidly which means that the bolometer detector will respond for high frequencies in a manner more speed than that of low frequencies.

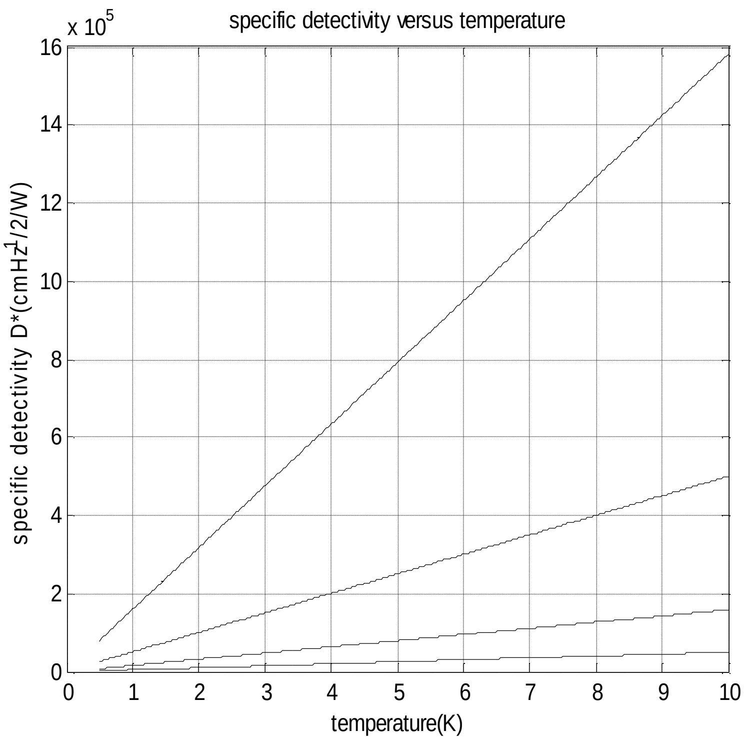

Figure (12): Specific Detectivity D* versus Temperature change for different frequencies. From below upward the curves represent frequencies of incident radiation for 1Hz, 10 Hz, 100Hz, and 1 kHz respectively. At higher frequencies the rise of D* for the same interval of temperatures is more rapid than low frequencies.

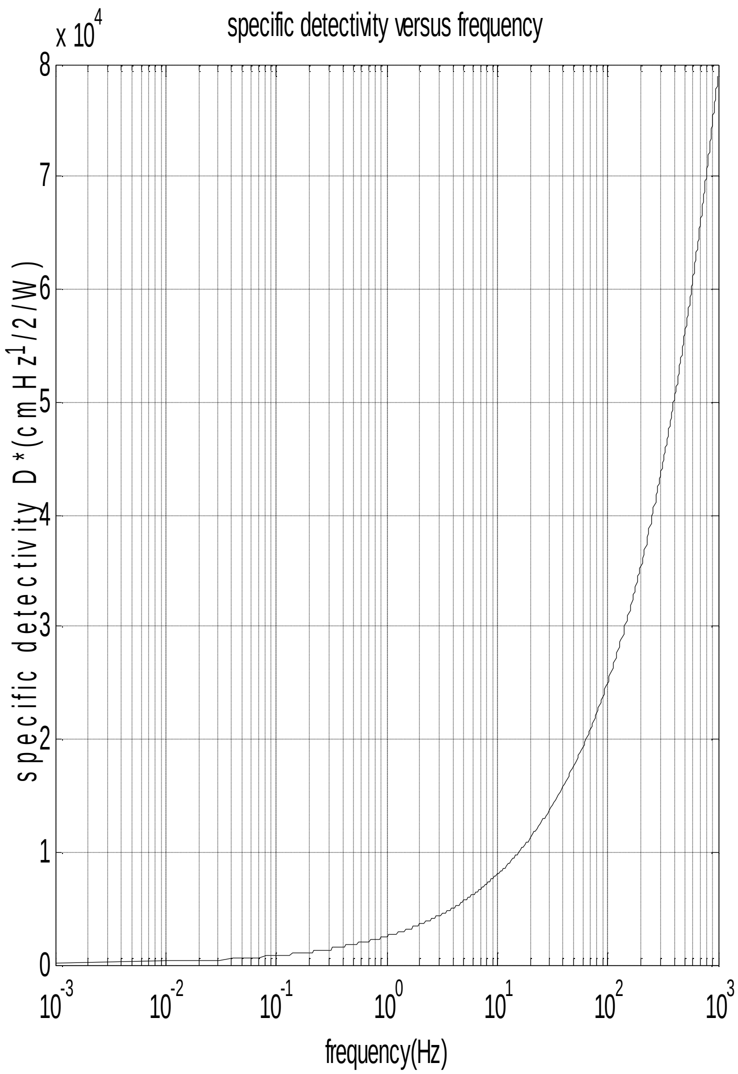

Figure (13): Specific Detectivity D* versus frequency of incident radiation.

CONCLUSIONS

This model has been investigated to understand the working concept and predicts the behaviour of bolometer detector. Using Matlab Package (Language), some values concerned with semiconductor material (germanium) were applied to demonstrate by simulation the main parameters affecting on the bolometer performance. This performance of bolometer is derived from the equations stated in this research and the results of this model can be compared with experimental results. This model includes the effect of radiation frequency on bolometer temperature change, output voltage, responsivity and specific Detectivity of bolometer.

The simulation results showed that a reverse relation between bolometer temperature change and its thermal time constant. So from this simulation, it is possible to apply another data belong to other materials of different thermal capacities and thermal links of different conductance to predict which material coincides with the property of lower value of thermal time constant from which the bolometer could be improved. The temperature variation of bolometer material for different extents is found to have an obvious effect on NEP. It is found that increasing the frequency of incoming radiation results in decreasing the NEP of the bolometer. Increasing the noise voltages with increasing the temperature of sensing material of bolometer detector requires an increase in NEP. The specific Detectivity of bolometer increases with increasing the frequency. And for specified interval of temperature, it is found that if the frequency of the incident radiation is increased, the specific Detectivity D* is also increase. Using decibel scale of measurement, it is found that bolometer response of temperature change, output voltage, and responsivity versus frequency of incident radiation work as a low pass filter.

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