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Thermal Radiation Detector (TRD) Modeling

Dr. Mehdi Munshid Shellal*

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Abstract

This paper describes the theoretical principles of TRD operation based on thermal absorption of incident power of radiation. In the modelling procedures, the main parameters influencing on the detector features have been introduced. So the this model allow us to predict the behaviour of different types of thermal detectors. It is found that the temperature response of the detector against the frequency of incident radiation in logarithmic scale describes the TRD as a typical low pass filter characteristics. The cut off corner frequency is found to be at 1 Hz under which the temperature change attains a saturation value. In the sense that the thermal detector will detect all the incoming radiations of higher frequency.

Keywords: Thermal radiation detector, Modeling, temperature change, thermal Response, frequency.

نمذجة كاشف الأشعاع الحراري

الخلاصة

تصف هذه المقالة المبادىء النظرية لعمل كاشف الأشعاع الحراري المبني على أساس الأمتصاص الحراري للأشعاع الساقط. لقد تم في اجراء النموذجة استعمال أهم المعلمات(المتغيرات) المؤثرة على مواصفات الكاشف. لذا فا ن هذا النموذج سيجيز لنا التنبؤ (التوقع) بتصرف الأنواع المختلفة للكواشف الحرارية. لقد وجد أن الأستجابة الحرارية للكاشف مقابل تردد الأشعاع الساقط في المقياس اللوغاريتمي أنها تصف كاشف الأشعاع الحراري على أنه يتصف بميزات مرشح الترددات الواطئة. حيث وجد أن تردد القطع يحصل عند(1 هيرتز)الذي عندما يكون تردد الأشاعاع السا قط اقل منه فان التغيرالحاصل بدرجة حرارة الكاشف ستبلغ قيمة التشبع. بمعنى أن الكاشف الحراري سيكشف جميع الترددات القادمه ذات التردد الأعلى من 1 هيرتز.

1. Introduction

Thermal detectors, simply, sense the incoming radiation by temperature modulation of the detector material. This change in temperature in turn results in changing the electrical properties of detector sensing material which exploited to measure the electrical outputs for several thermal detectors depending upon thermal effects such as pyroelectric, bolometer, thermopile, and Golay cell and related detectors.

Thermal detectors not affected by the wavelength of incident radiations as in quantum ones. In other words, the operation concept of TRD based on the energy absorption of incident photons which cause the temperature

* Laser and Optoelectronics Engineering Department, University of Technology/ Baghdad

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

increase of detector sensing element. The rate of temperature variation determines the accumulated energy conserved in the detector material.

The operating temperature range of TRD can be designed by selecting the appropriate metal used as sensing material. The detection efficiency of thermal detector is less than that of quantum detector due to the time required to absorbing and heating of detecting material.

The output of thermal detectors is usually proportional to the amount of absorbed energy per unit time by the detector material provided the absorption efficiency is the same at all wavelengths.

Because heating and cooling of a macroscopic sample is relatively slow process, thermal detectors as a class are slower in their rate of response than photon ones. It is convenient to think of thermal detectors as having millisecond response times and photon ones as having microsecond or less response times. In addition, those thermal detectors represent a chain of conversions which require interval of times to take place. It is hoped that this research will provide a brief introduction to the ideas of modelling and characterising thermal detectors, and has given an idea and understanding of how such detectors behave.

2. Thermal Radiation

This section deals with the characteristics of thermal radiation and radiation exchange, that is, heat transfer by radiation. The physical mechanism of radiation is not yet completely understood. Radiation energy is envisioned sometimes as transported by electromagnetic waves, at other times as transported by photons. Neither view point completely describes the nature of all observed phenomena. From the view point of electromagnetic theory, the waves travel at the speed of light which is equal to the product of the frequency and the wavelength of the radiation $c = \lambda \nu$, while from the quantum point of view, energy is transported by photons that travel at that speed. Although all the photons have the same velocity, there is always a distribution of energy among them. Where the energy associated with a photon is given by $E = h\nu = \frac{hc}{\lambda}$ where h is Planck's constant, ν and λ are the frequency and wavelength of radiation respectively. The wavelength of radiation depends on how the radiation is produced. *Thermal radiation* is defined as radiant energy emitted by a medium by virtue of its temperature, that is, the emission of thermal radiation is governed by the temperature of the emitting body. The wavelength range encompassed by thermal radiation falls approximately between 0.1 and $100\ \mu m$ which is subdivided into the ultraviolet, the visible, and the infrared [1].

3. Thermal Resistive And Capacitive Elements

Thermal (resistance, hence thermal conductance) and thermal capacitance are the two basic elements of a thermal circuit in general. The across variable which is measured across an element is the temperature T, and the through variable which flows through the element is the heat flux that is the heat flow rate q .

3.1 Thermal Resistance R_{th} :

Thermal resistance is a consequence of the fact that temperature difference is required to cause heat to flow. There are three different thermal resistance effects corresponding to the three modes of heat transfer, conduction, convection, and radiation. Thermal resistance is obtained from the constitutive relationship of the heat transfer mode [1, 2].

Fourier's law for one-dimensional heat conduction is given by

$$q = Ak\left(\frac{T_1 - T_2}{L}\right) = \frac{T_1 - T_2}{L / Ak} \quad \ldots (1)$$

Where:

$q = heat\ \ flow\ rate,\ kcal / \sec$

$A = area\ normal\ to\ heat\ \ flow,\ m^2$

$k = Thermal\ conductivity\ of\ \ the$

$\det ecting\ \ material, kcal / m \sec\ ^\circ c;$

$and\ \ L = Thickness$

$of\ \ that\ \ material, m.$

We see that equation (1) is analogous to Ohm's law in electricity relating the across and through variables for a resistance. Hence, thermal resistance due to conduction is defined by $R_{th} = L / Ak$. Heat transfer by convection is described by Newton's law of cooling as [1, 2]:

$$q = Ah(T_1 - T_2) = \frac{T_1 - T_2}{1 / Ah} \quad \ldots (2)$$

Where

$h = convection\ coefficient\ of\ \ heat$

$transfer, kcal / m^2 \sec\ ^\circ c$

The thermal resistance due to convection is defined as $R_{th} = 1 / Ah.$

The net heat flux by radiation between two bodies at absolute temperatures T_1 and T_2 respectively, is given by Stefan-Boltzmann law as [1]:

$$q = \sigma F_e\, F_{12}\, A_1 (T_1^4 - T_2^4) \quad \ldots\ldots (3)$$

Where

$\sigma = Stefan - Boltzmann\, cons \tan t$

$= 5.67 \times 10^{-8} W / m^2 K^4$

$F_e = Emissivity\ \ factor,$

$F_{12} = Geometric\ view\ \ factor,$ and

$A_1 = Surface\ area\ of\ \ the\ \ first\, body.$

(Noting that $F_{12}\ A_1 = F_{21} A_2$).

To linearize equation (3), we multiply and divide by $(T_1 - T_2)$ to obtain

$$q = \sigma F_e\, F_{12}\, A_1 (T_1^4 - T_2^4) \frac{(T_1 - T_2)}{(T_1 - T_2)} \quad \ldots (4)$$

Then, thermal resistance due to radiation is defined by

$$R_{th} = \frac{(T_1 - T_2)}{\sigma F_e\, F_{12}\, A_1 (T_1^4 - T_2^4)} \quad \ldots . (5)$$

Where the right hand side is evaluated at equilibrium conditions.

3.2 Thermal Capacitance C_{th}

Just as an electrical capacitor can store energy and a hydraulic capacitor can store fluid, the thermal capacitance C_{th} of an object is related to two physical properties; mass and specific heat at constant pressure:

$C_{th} = mc; m = mass\ \ [kg],$

$c = specific\ \ heat\ \ \ [J /\ ^\circ C.kg]$

Physically thermal capacitance is related to the ability of a mass to store heat, and describes how much the temperature of the mass will rise for a given addition of heat. If we add heat at the rate $q\ J/s$ for time Δt and the resulting temperature rise is ΔT, then we can define the thermal capacitance to be $C_{th} = \frac{heat\ added}{temperature\ rise} = \frac{q\,\Delta t}{\Delta T}$.

If the temperature rises from value $T_\circ$ at time $t_\circ$ to T_1 at time t_1, then we can write [3]:

$$T_1 - T_\circ = \Delta T\,(t) = \frac{1}{C_{th}} \int_{t_\circ}^{t_1} q\,(t)\,dt \qquad \text{…..} (6)$$

Or, in differential form,

$$C_{th} \frac{d\Delta T(t)}{dt} = q(t) \qquad \text{……} (7)$$

4. Thermal System Dynamics

To describe the dynamics of a thermal system, we write a differential equation based on energy balance. The difference between the heat added to the mass by an external source and the heat leaving the same mass (by convection or conduction) must be equal to the heat stored in the mass[1,2, 3].

$$q_{in} - q_{out} = q_{stored} \text{ ……} (8)$$

An object is internally heated at the rate q_{in}; its temperature is T and the ambient temperature is T_a, then $q_{out} = \frac{T(t) - T_a}{R_{th}}$; where R_{th} is thermal resistance of the system. From energy balance [3]

$$q_{in}(t) - \frac{T(t) - T_a}{R_{th}} = C_{th} \frac{d\Delta T(t)}{dt} \text{ . } (9)$$

Where the right hand side of (9) represents the stored thermal energy. Rearranging this equation according to inputs and outputs, we get

$$C_{th} \frac{d\Delta T(t)}{dt} + \frac{T(t) - T_a}{R_{th}} = q_{in}(t) \quad (10)$$

or

$$R_{th} C_{th} \frac{d\Delta T(t)}{dt} + \Delta T(t) = R_{th}\, q_{in}(t) \quad (11)$$

where $\Delta T = T(t) - T_a$. At steady state, the rate of change of temperature is zero, hence,

$$\Delta T(\infty) = R_{th}\, q_{in} \qquad \text{………} (12)$$

Figure 2.Equivalent electrical circuit of thermal system.

5. Thermal Detector Model

From the previous principles, it is easy now to sketch a thermal detector prototype. Let q_{in} be the radiation heat flux flowing into an element of a sensing thin metal which blackened to absorb most of the radiation incident upon it [4] and q_{out} be the heat flux flowing out. The difference $(q_{in} - q_{out})$ is stored by the element in the form of internal energy. For the case of thermal detector, the q_{in} can be represented by the absorbed energy P_{abs} by the detecting material. Therefore from (8) and (9) we have:

$$P_{abs} - q_{out} = C_{th} \frac{d\Delta T(t)}{dt} \text{ ……} (13)$$

The right hand side of equation (13) represents the stored or accumulated thermal energy in the sensing material of detector due to $d\Delta T(t)/dt$ which is the time average of temperature change. The thermal detector can be modeled by a simple thermal circuit represented by heat sink which regarded to be at a constant temperature T, sensing element of heat or thermal capacity C_{th} .Heat sink and detector sensing element are connected via a thermal link of heat conductance G_{th} as shown in Fig. 3.

It is possible therefore to accept the interpretation, that the capacitor of thermal sensor is loaded from current source ηP_{in} , induced by heat flux absorbed by the sensor [4, 5, 6].

The equivalent circuit in Figure 4 illustrates this interpretation.

Fig.3. Simplified model of a thermal detector used to derive the frequency response characteristics. The incoming radiation raises the sensing element temperature to be $\mathrm{T}+\Delta\mathrm{T}$. That is the time-dependent temperature difference between the detector and the heat sink is $\Delta\mathrm{T}(t)$.

5. Mathematical Modelling of Thermal Detector

From the black body concepts, the rate at which the energy absorbed by the inner mater of detector will equal the rate at which it is emitted. In many industrial applications, transmission of radiation, such as through a layer of water or a glass plate, must be considered. For a spectral component of irradiation, portions may be reflected, absorbed, and transmitted. It follows that

$$P_{in} = \eta_{ref.}P_{in} + \eta_{abs.}P_{in} + \eta_{trans.}P_{in}$$

From which

$$1 = \eta_{ref.} + \eta_{abs.} + \eta_{trans.}$$

Where $\eta_{ref.}, \eta_{abs.}, \eta_{trans.}$ are the reflectivity, absorptivity, and transmissivity respectively, of the detector sensing layer surface.

In many engineering applications, however, such as in the case of thermal radiation detector (TRD) model, the medium is opaque to the incident radiation. Therefore, $\eta_{trans.} = 0$ and the remaining absorption and reflection can be treated as surface phenomenon. It is therefore appropriate to say that the irradiation is absorbed and reflected by the surface, with relative magnitudes of $\eta_{ref.}$ and $\eta_{abs.}$ depending on the wavelength and the nature of the surface. So ($(1-\eta_{abs.})$ represents the fraction of reflected radiation[5].

In our model of thermal detector, we will concern with absorbed heat in the sensing material of detector. As mentioned previously, the absorbed heat is q_{in} which represents the input heat of radiation quantity received by the detector so that the temperature of the sensing element is $\mathrm{T}+\Delta\mathrm{T}$. Therefore during the same interval of time, the amount of heat lost through thermal conductor is $G_{th}\Delta T$ which represents the output heat. To transform these statements into a mathematical model, we assume that P_{in} is the power of incident radiation on the detector surface. P_{abs} is the absorbed fraction and $\eta_{abs.} = \frac{P_{abs}}{P_{in}}$ is the optical absorption efficiency(absorptivity) or the fraction of the incident radiation absorbed so that the actually absorbed power is $\eta_{abs.}P_{in}$.

For simplicity, η will be used instead of η_{abs}.

Applying equation (13), we obtain that

$\eta P_{in} - G_{th}\Delta T = C_{th}\dfrac{d(\Delta T)}{dt}$ which re-arranged to give the first-order differential equation;

$$C_{th}\frac{d(\Delta T)}{dt} + G_{th}\Delta T = \eta P_{in}(t) \quad .(14)$$

where $C_{th} = cm$ is the thermal or heat mass. Here $p_{in}(t)$ is the incident radiant power modulated at angular frequency ω.

6. Thermal Detector Model Solution

Solving (14) gives for the amplitude of the excess temperature and its phase difference corresponding to the absorbed power of incident radiation. There are three approaches can be used to solve or determine the temperature response ΔT of the thermal detector.

6.1 Background noise consideration

Taking the power $P_\circ$ of surroundings noise effect into account and the corresponding noise in temperature $\Delta T_\circ$. Accordingly, we assume that [1,2]

$$P_{in} = P_\circ + P_\omega e^{j\omega t} \quad \text{….(15)}$$

$$\Delta T = \Delta T_\circ + \Delta T_\omega e^{j(\omega t+\phi)} \quad \text{…...(16)}$$

Where ϕ is the phase difference of ΔT from P_{in}. We see from above assumptions that P_{in} and ΔT have time independent components plus time dependent components modulated at angular frequency ω. Substituting (15) and (16) into (14), we find at balance heat condition that

$$\Delta T_\omega = \left(\frac{\eta P_\omega}{G_{th} + j\omega C_{th}}\right) e^{-j\phi} \quad \text{…..(17a)}$$

$$\Delta T_\omega = \frac{\eta P_\omega}{G_{th}(1 + j\omega C_{th}/G_{th})} e^{-j\phi} \quad \text{…(17b)}$$

$$\Delta T_\omega = \frac{\eta P_\omega R_{th}}{(1 + j\omega C_{th} R_{th})} e^{-j\phi} \quad \text{...(17c)}$$

$$\Delta T_\omega = \frac{\eta P_\omega R_{th}}{(1 + j\omega \tau_{th})} e^{-j\phi} \quad \text{……(17d)}$$

All these equations are the same. From which we find that the amplitude ΔT_ω of excess temperature corresponding to the absorption of ηP_{in} of the incident radiation is expressed by

$$\Delta T_\omega = \frac{\eta P_\omega}{(G_{th}^2 + \omega^2 C_{th}^2)^{1/2}} \quad \text{…..(18)}$$

and also from which we find that the phase difference ϕ of ΔT_ω from P_ω expressed by

$$\phi = \tan^{-1}(\omega C_{th}/G_{th}) \quad \text{…….(19)}$$

6.2 Neglecting background noise effect

In this case no attention or care to the noise effect of background radiation, so (15) becomes:

$$P_{in} = P_\omega e^{j\omega t} \quad \text{…….. (20)}$$

Rearranging (14) and substituting (20) in it, we obtain

$$\frac{d}{dt}(\Delta T) + \frac{G_{th}}{C_{th}}\Delta T = \frac{\eta}{C_{th}} P_\omega e^{j\omega t} \quad \text{…. (21)}$$

Equation (21) is a first-order linear differential one is analogous to the standard form $\dfrac{dy}{dt} + p(t)y = Q(t)$, so to solve (21), we need to use the integrating factor which is

$$e^{\int p(t)dt} = e^{\int \frac{G_{th}}{C_{th}}dt} = e^{\frac{G_{th}}{C_{th}}t}$$

Multiplying both sides of (21) by the integrating factor, we obtain

$$e^{\frac{G_{th}}{C_{th}}t}\left(\frac{d}{dt}(\Delta T)+\frac{G_{th}}{C_{th}}\Delta T\right)=e^{\frac{G_{th}}{C_{th}}t}\frac{\eta}{C_{th}}P_{\omega}e^{j\omega t} \quad \ldots (22)$$

$$e^{\frac{G_{th}}{C_{th}}t}\frac{d}{dt}(\Delta T)+e^{\frac{G_{th}}{C_{th}}t}\frac{G_{th}}{C_{th}}\Delta T=\frac{\eta}{C_{th}}P_{\omega}e^{(\frac{G_{th}}{C_{th}}+j\omega)t} \quad \ldots\ldots (23)$$

Which can rewritten to be

$$\frac{d}{dt}(e^{\frac{G_{th}}{C_{th}}t}\Delta T)=\frac{\eta P_{\omega}}{C_{th}}e^{(\frac{G_{th}}{C_{th}}+j\omega)t} \quad \ldots\ldots.. (24)$$

Integrati*ng both sides of (24) with respect to t, we get

$$e^{\frac{G_{th}}{C_{th}}t}\Delta T=\frac{\eta P_{\omega}}{(G_{th}+j\omega C_{th})}e^{(\frac{G_{th}}{C_{th}}+j\omega)t}+c \quad \ldots\ldots (25)$$

From which we find that

$$\Delta T = ce^{-t/\tau_{th}}+\frac{\eta P_{\omega}e^{j\omega t}}{(G_{th}+j\omega C_{th})} \quad \ldots\ldots (25a)$$

Where c is a constant depending on the boundary condition and $\tau_{th}=C_{th}/G_{th}=C_{th}R_{th}$ is the time constant of the thermal detector. The value $1/\tau_{th}$ is positive and large enough to ensure that $e^{-t/\tau_{th}}$ decays faster than any growth of c. The solution (25a) is mathematically equal to that concerning a dual RC-circuit supplied by an angular frequency generator ω. It consists of a transient term that rapidly disappears and an oscillating term whose modulus is ΔT_{ω}, then (25a) becomes

$$\Delta T = \Delta T_{\omega}e^{j\omega t} \quad \ldots.. (25b)$$

Where the modulus magnitude is given by

$$\Delta T_{\omega} = \frac{\eta P_{\omega}}{G_{th}(1+\omega^2\tau_{th}^2)^{1/2}} \quad \ldots\ldots (26)$$

Comparing Equations (26) and (18) we find that they are the same. Equation (26) represents the temperature response of the thermal detector.

6.3 TRD Transfer Function concept:

The transfer function of a device describes its output in terms of its input. In this case the detector output signal represents how it responds to known inputs. The transfer function can be expressed in terms of either an equation or a graph. For analog output of thermal radiation detector, the transfer function expresses the relationship between the absorbed fraction (input) of the incident radiation and a temperature rise (output response). Consideration Figure 4, we show that thermal detector elements include thermal capacitance and conductance. They are connected in parallel, so their equivalent value represents the system transfer function. Accordingly, the thermal response is evaluated to be as follow

$$\Delta T = \left[\frac{\frac{1}{j\omega C_{th}}\times\frac{1}{G_{th}}}{\frac{1}{j\omega C_{th}}+\frac{1}{G_{th}}}\right]\eta P_{\omega}e^{j\omega t} \quad \ldots\ldots.(27)$$

$$\Delta T = \left[\frac{1}{G_{th}+j\omega C_{th}}\right]\eta P_{\omega}e^{j\omega t} \quad \ldots.(28)$$

$$\Delta T = \frac{\eta P_{\omega}e^{j\omega t}}{G_{th}(1+j\omega R_{th}C_{th})} \quad \ldots \ldots\ldots(29)$$

From (29) we find that the magnitude of thermal response is

$$\Delta T = \frac{\eta P_\omega}{G_{th}(1+\omega^2 \tau_{th}^2)^{1/2}} \quad \text{…....(30)}$$

Which coincides with the equations (18) and (26).

7. Thermal Detector Features

Equation (26) expresses the most features of thermal detectors. From which clearly it is advantageous to make ΔT as large as possible. To do this, thermal capacity C_{th} of the detector and its thermal coupling G_{th} to its surroundings must be as small as possible. This may be achieved by using thin absorbing element of small area (to reduce C_{th}). This means that the detector sensing material is constructed as thin as possible to minimize the heat capacity and thereby bring about the most desirable transient characteristics [7] and also using a fine connecting wire to the heat sink is desirable .

Equation (26) also shows that as ω is increased, the term $\omega^2 C_{th}^2$ will eventually exceed G_{th}^2 and then ΔT will fall inversely with ω. A characteristic thermal response time (thermal time constant) for the detector can therefore defined as :

$$\tau_{th} = \frac{C_{th}}{G_{th}} = C_{th} R_{th} \quad \text{…... (31)}$$

where $R_{th} = \frac{1}{G_{th}}$ is the thermal resistance. See equations (17a-17d) and (30). So for good response at a modulation frequency ω, it requires that $\tau_{th} << \frac{1}{\omega}$ [8, 9]. That is the thermal time constant of the detector must be much smaller than the time period of modulation in order for the detector to reach a steady state temperature during each period [10].

Once C_{th} has been fixed due to size considerations, then G_{th} cannot be made too small because of thermal resistance $R_{th} = 1/G_{th}$ from which small value of G_{th} being required for highest sensitivity, thus it may be necessary to adopt a compromise in the choice of G_{th}, see (31). The value of G_{th} also determines the magnitude of the temperature noise fluctuations.

8. Minimum Possible Value Of G_{th}

Actually, the minimum value of G_{th} obtainable is when energy exchange takes place by means of radiative exchange only. Let the thermal detector has a receiving area A of emissivity ε, then when it is in thermal equilibrium with its surroundings, it will radiate a total flux power proportional with: detector receiving surface area, surface emissivity, and forth power of temperature; that follows the Stefan-Boltzmann law [8, 11]

$$P = A\varepsilon\sigma T^4 \quad \text{…… (32)}$$

where σ is the Stefan-Boltzmann constant. If radiant power exchange is the dominant heat exchange mechanism, then G_{th} is the first derivative with respect to temperature of the Stefan-Boltzmann function; that is, the radiative component of thermal conductance of the detector due to radiation is $G_{RAD} = \lim_{\Delta T \to 0} \frac{\Delta P}{\Delta T} = \frac{dP}{dT}$, then from Eq. (32), we obtain

$$G_{RAD} = 4A\varepsilon\sigma T^3 \qquad \ldots\ldots(33)$$

9. Temperature Response Simulation And Results

Inspecting equation 26, it reveals that all parameters are constants except ω which regarded to be variable. So to investigate the performance of TRD model and accept its response, it is necessary to assume false values of concerning parameters. Let the absorption factor $\eta = 0.85$, the power of incident radiation flux is $10^{-6}\,Watt$, thermal conductance is $1.95\times10^{-3}\,W/K$, thermal capacity is $310\times10^{-6}\,W.\sec/K$, that is the thermal time constant is $159\times10^{-3}\,\sec$. Since we deal with radiation in the case of thermal detectors which already be modulated at some range of frequencies. So the frequencies can regard to be represented by a vector (range) of values. For simplicity, we start from 10^{-3} to end with $10^{3}\,Hz$. We have two plots; the first one is the magnitude (amplitude) of detector temperature change in micro Kelvin. Since it is found that the logarithmic characteristics of decibel concept is convenient for expressing the corner frequency which is essential to determine the frequency at which the detector start to response to the incoming modulated radiation. So in the second plot we introduced the decibel unit of measurement on the magnitude of temperature change. Both plots are plotted against the frequency. The curves are drawn on semi log graph paper, using the log scale for frequency and linear scale for magnitude. From Figures 3 and 4, it is found by simulation that the operation of this model continues for higher frequencies of incident radiation. So, increasing the range of frequency to attain 10^{6} Hz, it is found that the performance of our model of thermal detector is true, and we believe that this model is continue to work until more values of frequencies of incident radiation in the case of the available of computer of high speed and high capacity of memory. Inspecting the Figures, we see that the start point value of temperature change magnitude in micro Kelvin unit is the same for figures 1 and 3 and also true for figures 2 and 4 in the case of decibel unit.

From Figures 2, and 4 we see that the thermal detector is a device that passes radiation of low frequencies less than 1 Hz and absorbs radiation of higher frequencies. The region greater than 1 Hz is of high temperature change which means that the detector response is clear which can be read either as current or voltage according to the application or mode of measurement.

10. Conclusions

The simulated Figures which describe an proposed ideal thermal radiation detector resulted in investigation of TRD model allow us to predict the basic static and dynamic behaviour of thermal detectors such as bolometer, pyroelectric, thermopile, and others.

From Figures 2 and 4, it is clear that thermal detector responds to any radiation which its frequency greater than 1 Hz, that is, it is responds to any wavelength radiation that is absorbed. From inspecting the logarithmic scale of measurement of temperature change of TRD model , it clearly that this change portrays the typical low pass characteristics in which 1 Hz represents the cut-off frequency.

The cut-off or corner frequency results from the thermal time constant according to $f_c = 1/2\pi\tau_{th}$. Below the corner frequency, we see that the temperature change attains a saturation value in micro Kelvin depending on the values of its parameters which here found to be nearly 435 micro Kelvin(μK) according to the values assumed above. Above the corner frequency, the thermal detector, however, will responds to show a good or quick reaction with the incident radiation which in other words absorbed by detecting material. In the sense that the thermal detector will detect the incoming radiation and its response will depends on the type of its material or the type of the detector used and also depends upon the measurement mode and on the usage of preamplifiersFor a high responsivity and a high signal to noise ratio, a high temperature change ΔT is required, so the radiation sensitive material must characterized by high optical absorption efficiency η, low thermal capacity C_{th}. So the thickness of detector sensing element has to be very low. Compromises are necessary between thermal capacity and thermal conductance G_{th} to its surroundings(which is represented according to TRD by a heat sink with a given temperature T) because the reduction in G_{th} is opposed by the increase of thermal time constant τ_{th}.

The temperature attained by detector element is not only a function of the radiant energy absorbed, but is also dependent on the convection losses to the surroundings and conduction to the fixtures. So, the convection losses from the element may be reduced by enclosing the detector in an evacuated system with an appropriate window for transmission of the radiation.

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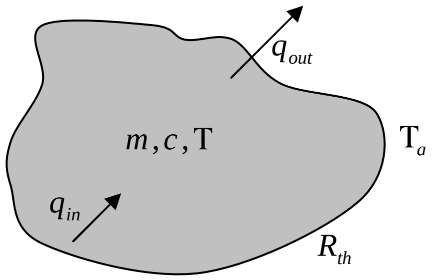

Figure (1) Schematic of general Thermal system

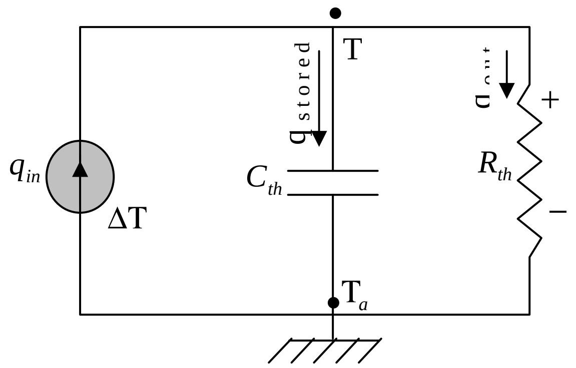

Figure (2) Equivalent electrical circuit of thermal syste

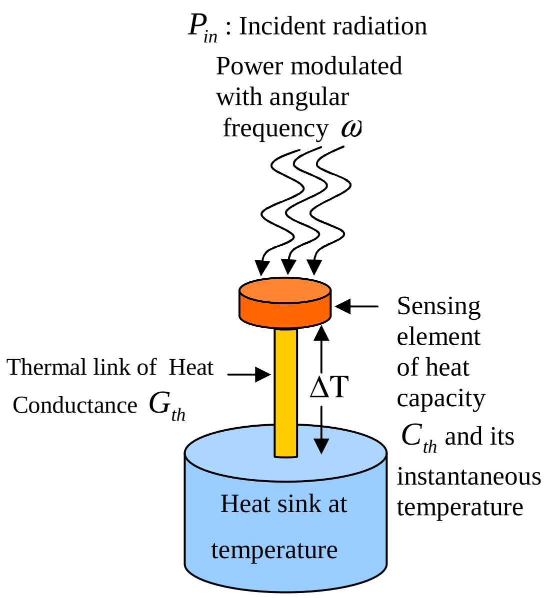

Figure (3) Simplified model of a thermal

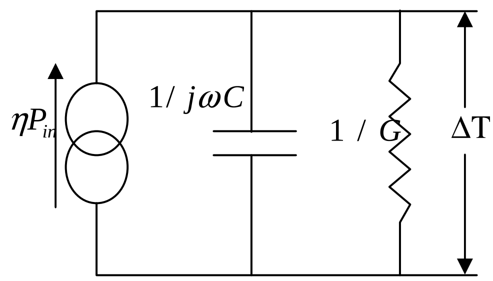

Figure (4) Equivalent electrical circuit of thermal detector model of Fig.3.

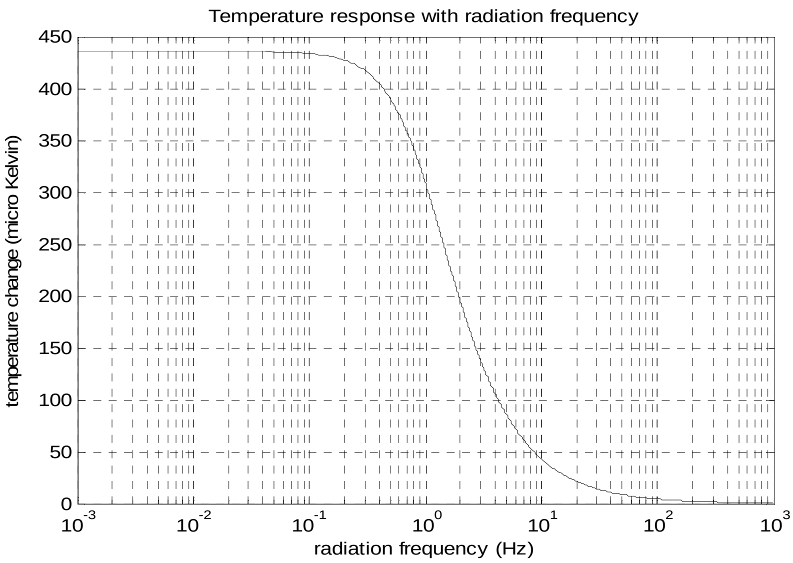

Figure 5: Temperature change in micro Kelvin against frequency for the interval from 10^{-3} Hz to 10^{3} Hz of Thermal radiation detector model.

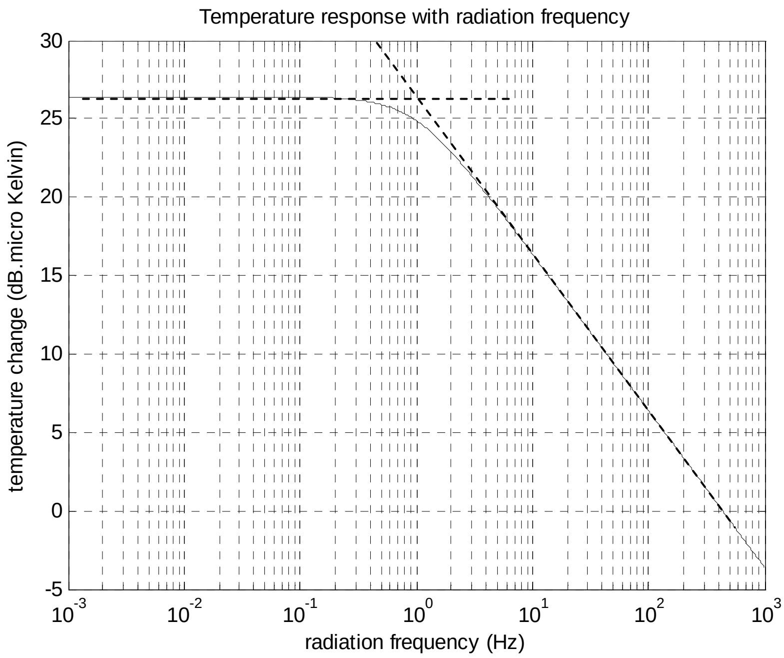

Figure 6: The decibel concept introduced here to determine the corner frequency at 1 Hz (intersection point of dashed lines) at which the response of thermal detector is start. We see that the temperature change in (dB. Micro Kelvin) versus frequency for the same parameters used simulating Fig.1.

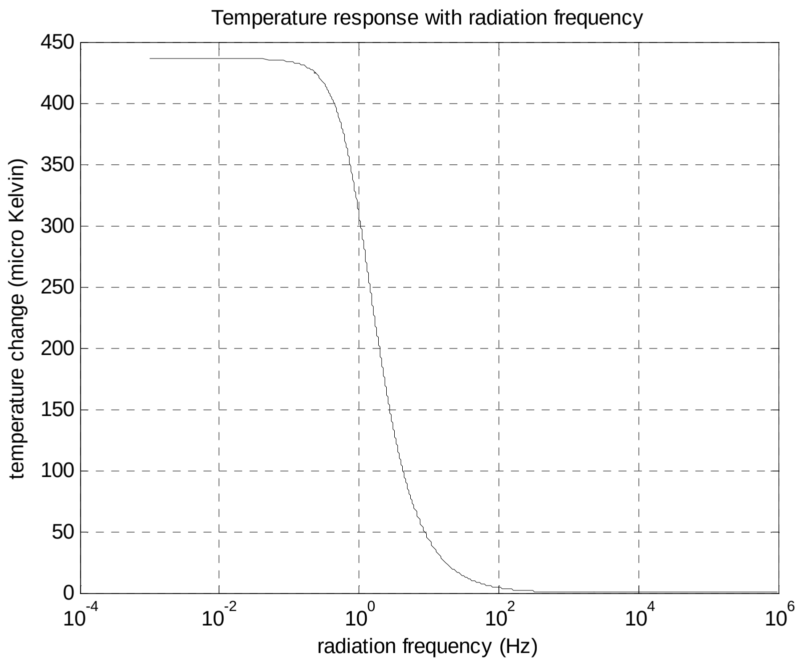

Figure 7: The temperature response versus frequency from 10^{-3} *to* 10^{6} Hz. You can compare with Fig. 1 to see the start points of the signal are the same.

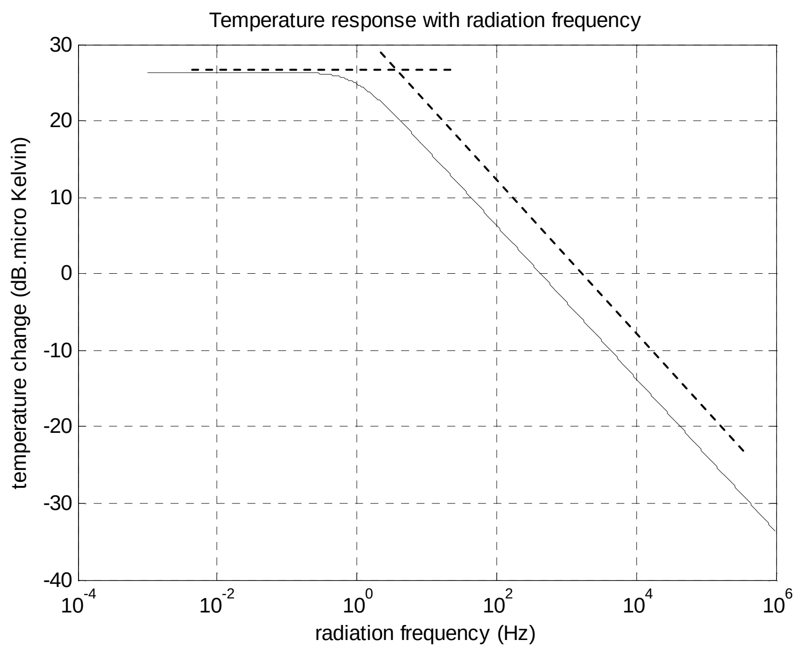

Figure 8: The temperature response when increasing the radiation frequency in terms of decibel scale from which we see that the corner frequency stays fixed at 1Hz. See the start point of the signal and c ompare with Fig. 2.