STM JOURNALS

Journal of
Microwave Engineering & Technologies

ISSN: 2349-9001
Volume 12, Issue 3, 2025
September–December
DOI (Journal): 10.37591/JoMET

https://journals.stmjournals.com/jomet

Research JoMET

Real-Time IR Intensity Measurement and Computation for Systems

R.S. Kawitkar[1], Prathamesh Chopade[2,*], Pratik Shinde[2], Suraj Sidankar[2]

Abstract

In contemporary defense mechanisms, infrared (IR) sensing has become a fundamental technology for identifying and neutralizing heat-seeking threats, especially concerning aircraft protection. Conventional IR detection systems, such as single-channel radiometers and basic thermal sensors, frequently face restrictions due to low spatial resolution, sluggish data processing, and inadequate user engagement. These constraints can impede the prompt identification of dangers like missile launches or flare activations, potentially endangering mission safety. Additionally, numerous traditional systems lack scalability and real-time processing capabilities, rendering them less effective in rapidly changing and hostile environments where swift situational awareness is essential. To tackle these issues, this study introduces a MATLAB-driven real-time IR intensity measurement and computation system specifically developed for multiple uses. This system can obtain and analyze IR data from distinct wavelength channels one at a time, offering a more detailed and directional insight into thermal activities surrounding an aircraft. By leveraging MATLAB's powerful graphical user interface (GUI), users can track real-time data feeds, execute signal processing, and interactively adjust parameters like gain, filtering thresholds, and sampling rates. Each channel in this system is linked to a unique IR sensor, strategically arranged to detect thermal signatures over a broader spatial area. These signals are transformed from analog voltages into digital data and displayed in real time, facilitating immediate evaluation of flare discharges or adversarial heat sources. The system also utilizes computational models, including Planck's Law, for estimating intensity, improving the precision of threat identification.

Keywords: Infrared (IR) sensing, real-time monitoring, flare detection, MATLAB GUI, data acquisition, signal processing, thermal signature, aircraft survivability, electronic warfare, threat detection, Planck's law, countermeasure deployment, defense technology, directional sensing, scalable system architecture

INTRODUCTION

The escalating intricacies of contemporary warfare and the increasing dependence on precise targeting have led to a heightened requirement for sophisticated detection and countermeasure systems. Infrared (IR) sensing technologies are crucial for spotting thermal irregularities that may suggest threats like missile launches, flare releases, or the presence of adversaries. Real-time detection of IR signatures is particularly vital in aerospace and defense contexts, where even a minor delay in detection could jeopardize aircraft safety. Standard IR systems typically utilize single-channel radiometers or passive infrared detectors, which are limited in terms of spatial resolution and response time. These systems generally experience lag in signal processing and offer minimal control to users, resulting in restricted situational awareness.

***Author for Correspondence**
Prathamesh Chopade
E-mail: prathameshchopade.scoe.entc@gmail.com

[1]Professor, Department of Electronics and Telecommunication Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India
[2]UG Student, Department of Electronics and Telecommunication Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India

Received Date: June 02, 2025
Accepted Date: June 07, 2025
Published Date: September 10, 2025

Citation: R.S. Kawitkar, Prathamesh Chopade, Pratik Shinde, Suraj Sidankar. Real-Time IR Intensity Measurement and Computation for Systems. Journal of Microwave Engineering & Technologies. 2025; 12(3): 8–13p.

Moreover, traditional detection configurations are usually closed-loop and challenging to modify or scale based on mission-specific needs [1].

Recent developments in embedded computing platforms and high-level tools like MATLAB have created new possibilities for designing modular and real-time IR detection systems. MATLAB is particularly advantageous as it provides integrated features for data acquisition, signal processing, and user interface development, making it ideal for crafting threat monitoring systems. Moreover, effective hardware interfacing via Ethernet and real-time data streams has facilitated the development of responsive and adaptable systems suitable for battlefield situations [2].

This study introduces a cutting-edge, MATLAB-based IR intensity monitoring and computation system that overcomes the challenges faced by traditional methods. The proposed design employs spatially distributed IR detectors to capture thermal data in real-time. These analog voltage outputs are digitized, processed, and presented via a custom-designed MATLAB Graphical User Interface (GUI). The graphical user interface (GUI) provides users with an intuitive platform to monitor signal trends in real time. It allows for dynamic adjustment of key parameters such as gain and filter thresholds, enhancing data accuracy and customization. Users can simultaneously visualize intensity changes across all channels, facilitating comprehensive signal analysis. The GUI's interactive design improves user experience by offering immediate feedback and visual clarity, making it easier to detect anomalies or significant variations. This functionality supports efficient data interpretation and system control, making it an essential tool for professionals working in signal processing and monitoring environments [3].

In addition to simple intensity measurement, the system incorporates signal filtering, direction estimation, and intensity modeling by Planck’s radiation law [4]. This theoretical basis provides precise spectral analysis and reliable differentiation between background heat and potential threats. The modular framework of the system also facilitates seamless expansion to additional channels or integration with automated countermeasure deployment systems, such as flare launchers or electronic jammers. In comparison to earlier studies on IR detection and flare countermeasures, our system showcases improved responsiveness, real-time visualization, and user customization, crucial elements in the fluid dynamics of modern combat environments. This research offers a practical and scalable approach for real-time IR monitoring that can be tailored for a range of defense, environmental, and industrial applications.

SIGNIFICANCE OF IR INTENSITY MEASUREMENT

Industrial Processes

The measurement of infrared (IR) intensity is essential in contemporary industrial systems where precise temperature management is paramount. Industries such as metal forging, plastic molding, semiconductor production, glass manufacturing, and food processing require accurate thermal regulation to ensure product quality and safety in operations. Conventional contact-based temperature sensors like thermocouples or RTDs may not be appropriate in high-speed or high-heat environments. IR sensing provides a non-intrusive, real-time means of monitoring surface temperatures and thermal variations without disrupting the production process. For example, IR cameras can identify inconsistent heating in rolling mills or flaws in heat-treated materials, facilitating predictive maintenance and optimizing energy efficiency. By incorporating IR intensity measurement into automated systems, industries can achieve improved process control, minimized downtime, and enhanced compliance with safety standards [5].

Security

In the industry, IR intensity measurements are crucial for surveillance, target identification, and threat detection. Thermal imaging technologies can capture the heat signatures of aircraft, missiles, tanks, or personnel, even in adverse visibility conditions like fog, smoke, or nighttime settings. A key application of IR sensing involves detecting missile launches, which create a unique thermal plume. Monitoring swift changes in IR intensity can activate onboard systems to deploy countermeasures such as flares or chaff, potentially protecting the aircraft and its crew. An IR system, as suggested in this study, introduces directional capabilities, determining not only the existence of a threat but also its approach angle. This greatly enhances response accuracy in electronic warfare scenarios [6].

ENVIRONMENTAL MONITORING

Infrared intensity data serves as an important resource in environmental research and disaster management. Satellites and drones fitted with IR sensors can track surface temperature changes across forests, oceans, and urban areas. These measurements are vital for observing climate change patterns, detecting urban heat islands, and forecasting natural disasters. For instance, rising ground temperatures surrounding a volcano may indicate a potential eruption, while early identification of unusual heat spots in forests can help avert large wildfires. By facilitating real-time heat map visualizations, IR systems enable scientists, first responders, and environmental organizations to make quicker, well-informed decisions, ultimately conserving lives and resources (Figure 1) [7].

Experimental Setup

1. *Flares:* Flares in aircraft refer to a type of pyrotechnic device used primarily to decoy heat-seeking missiles. They typically consist of a combination of magnesium, strontium, and other chemicals that burn at high temperatures, generating a strong IR signature.
2. *Radiometer:* It is an instrument used to measure the intensity of radiant energy, particularly in the IR spectrum. It consists of three IR detectors, which work on the basis of the principle of the Photovoltaic effect. It will detect those signals that are fed by the optical filter and convert those signals into the form of an analog voltage signal (generally in mV) [7].
3. *Spectroradiometer:* A spectroradiometer is a type of instrument that measures the intensity of IR light across a range of wavelengths.
4. *GUI:* The Graphical User Interface in MATLAB is the final processing and display unit. The GUI is used for data acquisition, composition, and visualization of IR intensity data from three channels.

INTENSITY MEASUREMENT

We can calculate the intensity in the IR region by using the intensity in the visible region using Planck's quantization law (Figure 2).

The formula for Planck's law is given by:

$$B(\lambda, T)=\frac{2hc}{\lambda^5}\frac{1}{\frac{hc}{e\lambda k}}$$

Where,

B (λ, T) is the spectral radiance (intensity) at a given wavelength (λ) and temperature (T),
h is Planck's constant (6.626×10^{-34} J.s),
C is the speed of light (3×10^{8} m/s),
k is the Boltzmann constant ($1.38\times10^{-23}\frac{J}{K}$),
T is temperature in Kelvin.

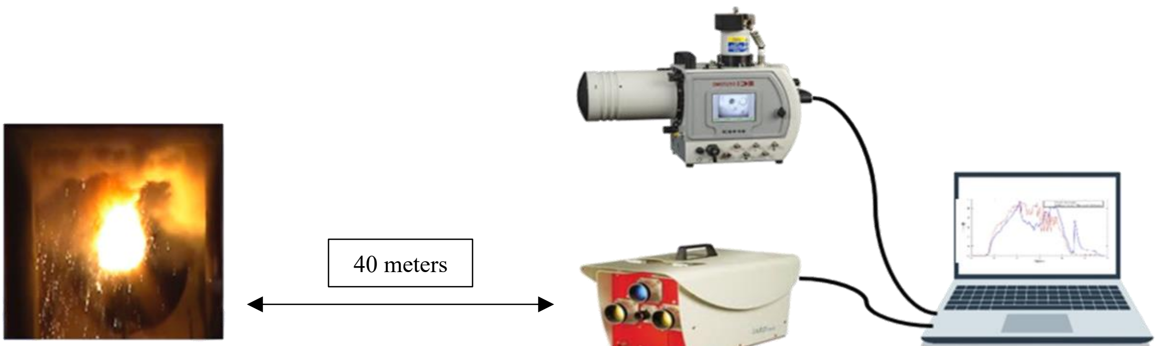

Figure 1. Experimental setup.

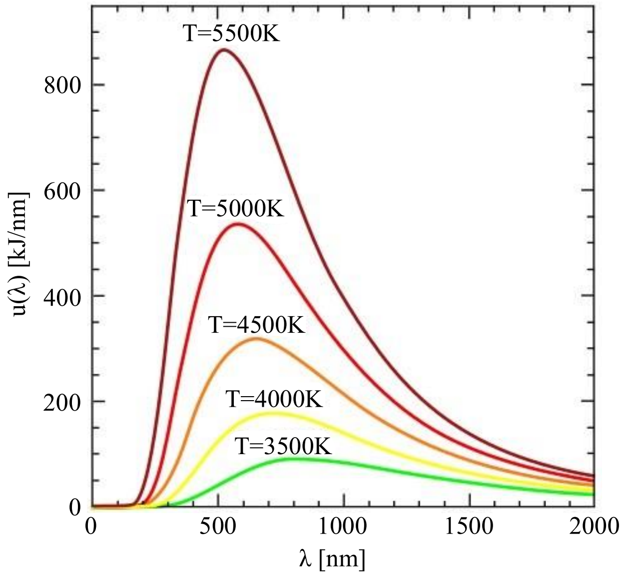

Figure 2. Planck's law.

Intensity formula: $\frac{S_t}{S_{bb}} \times A_{bb} \times P_l \times e$

Where,

S_t= Target signal,
S_{bb} = Black-body signal,
A_{bb} = Area of Black Body,
P_l = Planck's constant, and
e = emissivity.

APPLICATIONS

Military Aircraft Defense Systems

One of the primary applications of this system is in military aircraft, where the detection of sudden spikes in IR intensity can signal events such as missile launches, hostile fire, or explosive activity. By acquiring data from five different IR channels placed at strategic positions around the aircraft, the system helps determine not only the presence of a threat but also its direction of origin. This directional awareness enables quicker and more precise deployment of countermeasures such as infrared flares, chaff, or electronic jamming systems, thereby enhancing aircraft survivability in hostile environments (Figure 3) [8].

Defense Research and Development

In defense R&D labs, the system serves as a valuable experimental tool. Researchers can evaluate the performance of IR countermeasures such as flares, stealth materials, or thermal masking techniques. By simulating battlefield scenarios, the system's real-time GUI allows for live monitoring of thermal emissions and enables data logging for analysis. This controlled setup ensures high repeatability and precision, supporting the iterative improvement of technologies designed to reduce or alter infrared signatures for stealth operations [9].

Surveillance and Reconnaissance Missions

The channel configuration is ideal for wide-area thermal monitoring, making it suitable for deployment on UAVs (Unmanned Aerial Vehicles), satellites, or even ground-based observation towers. It can continuously scan large regions to detect moving heat sources, monitor covert troop movements, or identify camouflaged vehicles and equipment. This kind of persistent thermal surveillance is crucial for border security, search and rescue operations, and intelligence gathering in conflict zones [10].

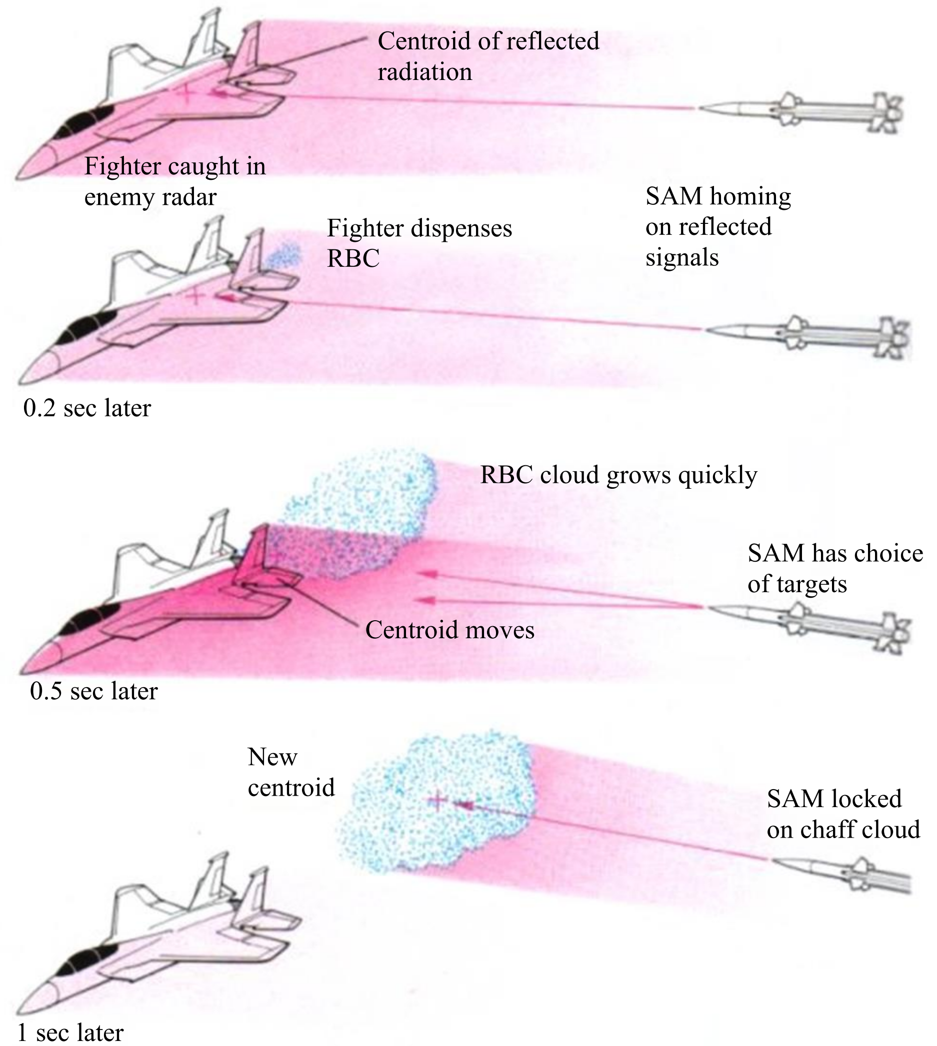

Figure 3. Aircraft deploying chaff countermeasures to divert radar-guided missile.

CONCLUSION

This study introduces a comprehensive, real-time monitoring and computation system for infrared (IR) intensity tailored for distinct wavelength channel uses in defense and related sectors. By utilizing MATLAB and incorporating spatially distributed IR sensors, the system achieves high precision in detecting thermal signatures, ascertaining the direction of infrared sources, and facilitating prompt countermeasure responses. In contrast to conventional IR detection systems that are constrained by single-channel input and slow reaction times, this design provides modularity, instantaneous signal processing, and an intuitive graphical interface through a custom-designed GUI.

The experimental configuration confirms the system's effectiveness in real-time situations, offering clear visual outputs and dynamic control over parameters such as gain, filter thresholds, and sampling rates. This advancement significantly improves situational awareness in hostile conditions, particularly for military aircraft defense missions. Apart from defense applications, the system shows promise in industrial monitoring, environmental observation, and disaster management due to its adaptability and scalability. Future developments will concentrate on incorporating intelligent algorithms like machine learning for automated threat detection and predictive analytics. Potential enhancements may also include wireless data transmission for UAV or satellite applications and expanding the system to support more than five IR channels for better spatial resolution. Overall, this research provides a solid groundwork for the next generation of IR sensing systems across various industries.

Acknowledgment

We would like to express our heartfelt thanks to Dr. R. S. Kawitkar for his invaluable guidance, technical expertise, and ongoing support throughout this research endeavor. His knowledge and mentorship played a crucial role in influencing the course and execution of this project. We also extend our gratitude to the faculty at Sinhgad College of Engineering, Pune, for their academic assistance and encouragement during the development of this work.

REFERENCES

1. Singh YK, Chaudhuri BB. MATLAB programming. India: PHI Learning Pvt. Ltd.; 2007 Jun 13.
2. Sarma KK. Matlab: Demystified Basic Concepts and Applications. India: Vikas Publishing House; 2010.
3. Emilio MD. Data acquisition systems. Cham, Switzerland: Springer. 2013.
4. Mudau AE, Willers CJ, Hlakola MJ, Le Roux FP, Theron B, Calitz JJ, Du Plooy MJ. Infrared measurements in defence application. Measurement and Instrumentation Technical. 2011 Mar; 55–57.
5. Decotignie JD. Ethernet-based real-time and industrial communications. Proc IEEE. 2005 May 31; 93(6): 1102–17.
6. Halliday D, Resnick R, Walker J. Fundamentals of physics. John Wiley & Sons; United States. 2013 Aug 13.
7. Li N, Su Z, Chen Z, Han D. A real-time aircraft infrared imaging simulation platform. Optik-International Journal for Light and Electron Optics. 2013 Sep 1;124(17):2885–93.
8. White JR. Aircraft infrared principles, signatures, threats, and countermeasures. CA: NAWCWD Technical Publication 8773; 2012 Sep 26.
9. Aghaei M, Gandelli A, Grimaccia F, Leva S, Zich RE. IR real-time analyses for PV system monitoring by digital image processing techniques. In 2015 IEEE international conference on event-based control, communication, and signal processing (EBCCSP). 2015 Jun 17; 1–6.
10. Tofail SA, Mani A, Bauer J, Silien C. In Situ, Real-Time Infrared (IR) Imaging for Metrology in Advanced Manufacturing. Adv Eng Mater. 2018 Jun; 20(6): 1800061.

