

Infrared measurements in defence application

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The optronic sensor systems (OSS) competency area (CA) at the CSIR unit for defence, peace, safety and security (DPSS) performs directed research and development and builds technology demonstrators in the fields of optical design, modelling, long-range surveillance, earth observation, imaging using infrared (IR) thermal imaging systems, image processing, camouflage, simulation, the evaluation and optimisation of military IR systems and protection of military personnel and equipments against observation and hostile missiles.

The CA has been involved in field and laboratory signature and flare measurements as early as 1965 and has been using infrared imaging systems for airborne infrared countermeasure (IRCM) flares measurements since the early 1990s. Modelling and simulation depend heavily on measured data to achieve realistic predictions, and is further more dependent on measured data for validation. The CA performs laboratory and field measurements in the infrared spectral region, which serves inter alia, for design and optimisation of IRCM. As such, results of measurements will impact directly on the survival and safety of humans and equipment, e.g. protecting an aircraft and its personnel against an approaching missile. The design, and ultimately, the effectiveness of its performance depend on the validity of the simulation results which affected design decisions.

This article briefly summarises the results of reference measurements performed during field infrared measurements trials. The results were compared to the results obtained using a handheld infrared thermometer to ensure the validity of radiometric temperature

measurement technique in support of IRCM flare measurements.

Measurements processes

An important requirement during field trials is a deep scientific understanding of the measurement equipment, measurement processes or protocols, the unit under test (UUT) and the effects of the environment on the measurement outcome. Since the measurements and tests are done both in laboratory and field environments, it is important to understand and account for the influence of the environment on the measurement outcome. In addition, consistently disciplined measurement practices are required, e.g. via suitably documented measurement procedures (protocols), traceability to the international system of units (SI), data management, and accurate log recording methodology. To improve the value of the measurement protocols, researchers at OSS are continuously using, evaluating and reviewing these protocols under laboratory and field trial conditions.

Infrared homing missiles

IR homing "heat seeking" missiles such as surface-to-air missiles (SAM) and air-to-air missiles (AAM) remain major threats to military and civilian aircraft. Since 1996, 20 'non-state' attacks worldwide were reported, and during 1999 – 2001 more than 150 illegal missiles were seized. IR seeker missiles are designed to detect the IR signature of an aircraft. The signature of the aircraft is mainly contributed by the engine hot parts, exhaust plume, rear fuselage, and the skin of the airframe, due to the thermal emission resulting from aerodynamic heating, internal heat sources and the reflected ambient radiation from the sun, the sky and the ground.

Infrared counter-measures

To mitigate the threat posed by IR seeker missiles, military and civilian aircraft are equipped with IRCM systems. IRCM systems are designed to defeat both surface-to-air and air-to-air missiles by detecting the ultraviolet (UV) or IR radiation from the missile plume (the exhaust trail from the missile) and then initiating countermeasures.

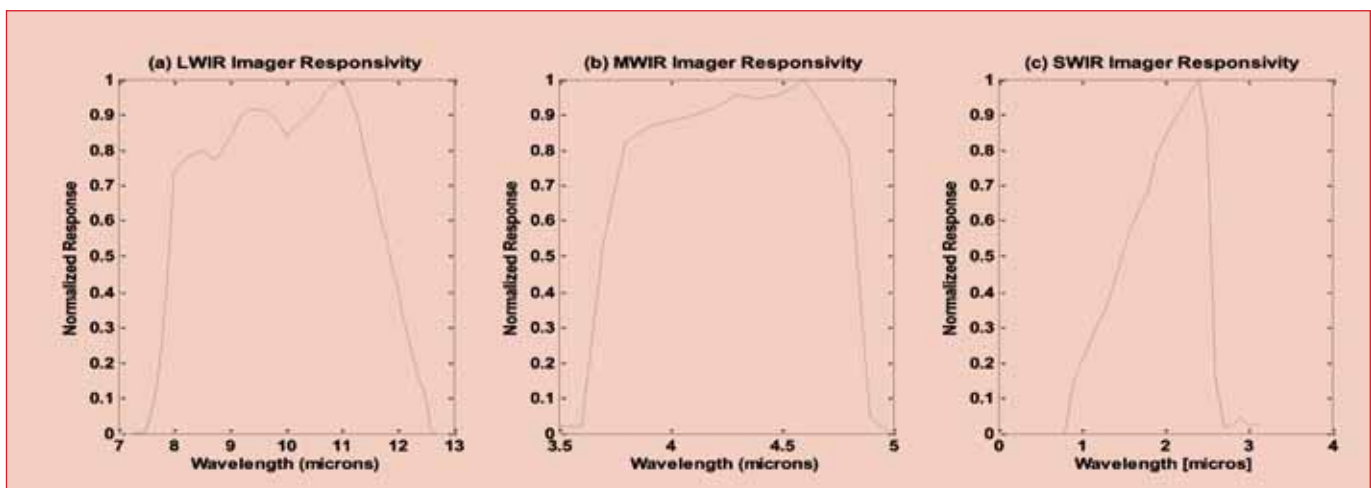


Fig. 1: Spectral responsivity of the Jade thermal imagers.

MWIR IR Thermal Imager	Fluke (± 2)	Percentage difference (%)
777,83 $\pm$ 4,60	751,15	1,75
783,37 $\pm$ 3,42	752,35	2,00

Table 1: Example summary of temperature measurement results.

Countermeasures can be classified in two groups, passive and active IRCM systems. In passive IRCM, the IR signature of the aircraft is suppressed or minimised in order to prevent missile lock-on and tracking, whereas in active IRCM the IR seeker is decoyed, confused or jammed using an active source, such as a countermeasure flare or a laser source, which causes missile guidance systems to abruptly steer away from the target aircraft.

IRCM flares

Airborne IRCM flares are defensive mechanisms employed from military aircraft to avoid detection and attack by enemy infrared seeker missiles. The flares are designed to present a more attractive IR signature than the target and thus seduce or decoy the missile seeker away from the aircraft into tracking the flare. Furthermore, the flares are also used to confuse the threat by saturating its processing or discrimination circuitry. The older generation, widely used, pyrotechnic flares are based on compositions of magnesium and Teflon (polytetrafluoroethylene), and are commonly referred to as MTV flares. These flares have properties of high-energy content, low hygroscopicity, high degree of safety in preparation; low temperature and pressure dependence of the burning rate, ease of ignite pellet or grain fabrication, favourable aging characteristics, stable burning at low pressure and low production costs. The properties of MTV flares are widely disclosed in the open literature.

Radiometric measurement

In order to model airborne IRCM flares effectively and correctly as missile countermeasures, it is crucial to know the temporal and spatial distribution of radiant intensity, emissivity and temperature. This information is obtained by measuring the flare using IR thermal imagers (covering the long wave infrared (LWIR), the medium wave infrared (MWIR) and the short wave infrared (SWIR) spectral bands, see Fig. 1). IR thermal imagers have been used in military applications for many years. An IR thermal imager is a camera that provides a picture of the electromagnetic energy radiated in the IR spectral band from an object. When IR thermal imagers are used to measure the temperature, there are three issues that need to be addressed: the first is the spectral emissivity of the unit under test and the second one is the influence of spectral atmospheric path radiance and thirdly the spectral absorption losses caused by the atmospheric constituents. The emissivity determines the ability of the unit under test to absorb and emit thermal radiation. In order to correct for atmospheric effects, the atmospheric path radiance and transmission are calculated using MODerate spectral resolution atmospheric TRANsmission (MODTRAN) code. The OSS infrared measurement team use a Fourier transform infrared imaging spectrometer to address the emissivity issues prior to radiometric temperature measurements using IR thermal imagers.

Radiometric temperature measurement is the measurement of temperature based on thermal radiation. This is attractive in many challenging temperature measurement situations because it is a noncontact, nonintrusive, and fast technique. This technique determines an object's surface temperature by measuring the amount of infrared energy radiated by the object's surface. The underlying principle of this technique is that at any temperature above 0°K (absolute zero) every object emits thermal radiation. Thermal radiation is governed by fundamental physical laws, such as Planck's radiation law, Wien's displacement law, Stefan-Boltzman law, and Kirchhoff law.

Reference measurements

It is necessary to verify correct instrument operation during the course of the trial. For this purpose, reference measurements are made. A reference measurement is a measurement of an object with a known radiance – a blackbody thermal radiation source (emissivity very close to unity) is normally used for this purpose. If the signal recorded by the IR thermal imager for the reference source is correct, it is reasonable to expect the measurement of IRCM flares to be correct. Reference measurements are typically made at the start and end of a measurement session, but could sometimes be done after each test point.

Measurements were performed using MWIR thermal imager and Fluke 574 handheld Infrared Thermometer. Fig. 2 shows the IR image of the blackbody acquired using MWIR thermal imager located 420 m away from the blackbody. The surface temperature of the blackbody was measured using the Fluke handheld infrared thermometer at the same time the IR image was captured.

Results and discussions

Fig. 3 shows the temperature of the blackbody as a function of time determined from IR thermal imager. Notice the temperature variation vs. time and the difference in the temperatures measured using the MWIR thermal imager and the Fluke measurements in Table 1. The temperature variation versus time observed in Fig. 3 and the difference in Table 1 is attributed by the attenuation of the radiant output of the blackbody, optical losses, or atmospheric attenuation and non-uniformity of the surface of the blackbody.

Table 1 shows the average temperature from a MWIR IR thermal imager with their standard deviation and the temperature measured using the Fluke 574 handheld IR thermometer.



Fig. 2: IR image of the blackbody before infrared measurements trials.

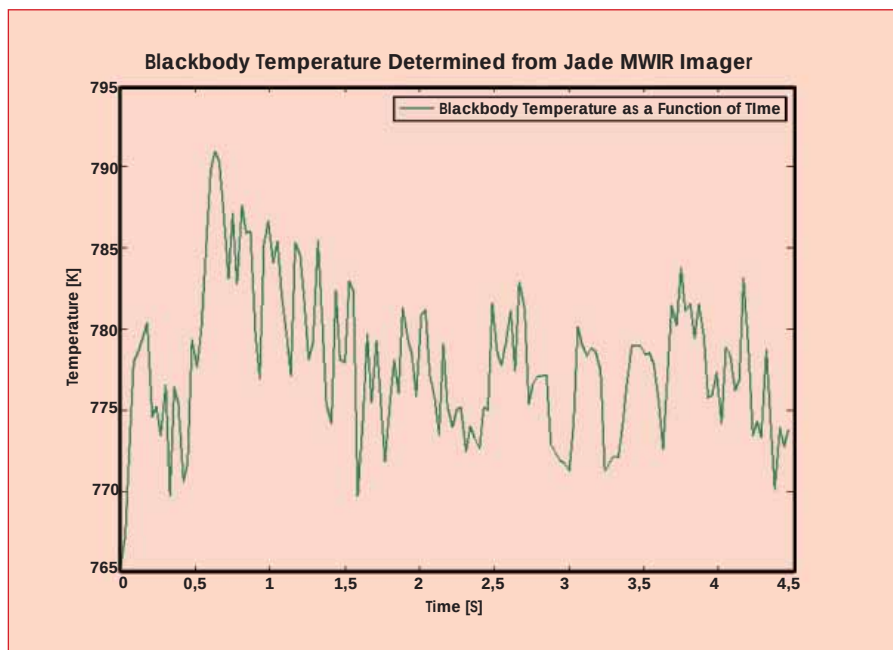


Fig. 3: Reference measured temperature as a function of time.

The percentage difference obtained is small. This serves to provide confidence between the temperature from Jade MWIR thermal imager and the Fluke images.

Conclusion

The results of the infrared imager versus that of the handheld infrared thermometer were compared to ensure the validity of the infrared imager temperature measurement technique. The use of reference source measurements, during the course of the field trial is essential to ensure confidence in the measured data.

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