High-Performance FLIR Testing Using Reflective-Target Technology

The extraordinary target-detection capability of current infrared imaging systems was dramatically demonstrated during the war in the Persian Gulf. New systems currently under development, such as those using advanced focal plane technology, will provide even greater performance. However, these advances in FLIR (forward-looking infrared) technology are threatening to surpass the capabilities of the IR test equipment - the blackbodies and target projectors - used to characterize them. In response, a new approach to IR target projection has been developed. This approach will allow testing technology to keep pace with the ever-increasing demands of the advanced FLIRs.

A FLIR creates a real-time image of an infrared scene and displays it on a monitor. FLIRs are characterized by both sensitivity and spatial resolution. Sensitivity is a measure of the minimum temperature difference that can be detected. Spatial resolution is a measure of the size of the details that can be resolved. State-of-the-art FLIRS have sensitivities approaching 0.01°C and spatial resolutions of better than 100 μrad.

FLIR testing

FLIRs are tested for a variety of performance parameters. Of key importance is the minimum resolvable temperature difference (MRTD), which provides an overall measure of system sensitivity and resolution. The MRTD is the temperature difference (ΔT) between a target and a blackbody located behind it at which the target features are just discernible.

Figure 1 shows a traditional target-projection system used to measure MRTD. Four-bar targets of known spatial frequencies provide the required image detail. These targets are metal plates with the target features machined through them and coated with a high-emissivity surface finish. The ΔT between the target and the blackbody is adjusted until the image of the bars is just visible in the FLIR display. This ΔT value is plotted against the target spatial frequency to provide the characteristic MRTD curve (Figure 2).

As new FLIRs with improved performance are developed, test systems must also improve if the performance limits of these FLIRs are to be accurately measured. New-generation blackbody sources have improved to keep up with the advanced FLIRs, leaving the targets as the weak link in the test equipment.

Practical problems

According to Curtis Webb of the US Army's CECOM Center for Night Vision and Electro-Optics, "The most critical sources of error in measuring MRTD functions are the thermal nonuniformity of the reference background [target], coupled with errors in measurement of its temperature."

These concerns point out the limitations of traditional infrared targets: At the performance level of the latest FLIRs, target temperature is nonuniform and difficult to measure. The nonuniformities exist because the target absorbs heat from the blackbody behind it. Other factors such as air currents contribute to this problem. This nonuniformity in turn affects the accuracy with which the target temperature can be measured. These effects are particularly pronounced in targets with small features (high spatial frequencies), which are the targets in increasing use as FLIR resolution improves.

The magnitude of these problems increases in the commonly used MRTD test setup where multiple targets are mounted in a wheel to allow easy selection of target size. There are practical problems associated with temperature measurement of a target mounted in a wheel. Some systems use a temperature sensor mounted in the wheel itself, relying on the thermal conductivity of the wheel to bring it and the target to the same temperature. The best results to date have been achieved with this approach. Other systems use a temperature sensor that rolls or slides along the surface of the wheel. This keeps the sensor closer to the wheel. This keeps the sensor closer to the target in use, but seriously degrades the thermal coupling between the sensor and the target.

Another problem with conventional targets is the difficulty in obtaining a uniform high-emmissivity surface. Unless the coatings are applied with extreme care, they can build up on the edges of the target features and partially fill in target details. Targets with fine details are fragile, making them particularly difficult to coat.

A new approach

In response to these problems, Santa Barbara Infrared (SBIR) has developed a new collimator system (patent pending) that uses reflective targets in place of the conventional emissive targets (Figure 4). The approach was originally developed for a specific critical military application, but is now commercially available in SBIR's Reflective-Target collimators. The background radiance in this system is provided by a high-emissivity background plate, rather than by the target itself. The temperature sensor that was formerly mounted in the target is now mounted in this background plate.

This approach solves the problems with emissive targets. The background plate is not located directly in front of the blackbody, and has no small features, so thermal nonuniformities are substantially reduced. The background plate is a homogeneous block, enabling highly accurate measurement of its temperature. The effects of any residual thermal nonuniformities in the plate are further reduced because the plate is not at the focus of the collimator. The result is an extremely uniform target image.

Targets can be easily changed during testing, since it is no longer necessary to move the temperature sensor from one target to the next. Measurement of target temperature in a wheel is no longer a problem - all of the targets are reflecting energy from the same background plate. Target wheels can even be made in the form of quick-change cassettes, since the temperature sensor is not embedded in the wheel. Each cassette can contain the targets needed to test a particular FLIR. A single test system with multiple cassettes can now support a variety of FLIRs.

The high-emmissivity coating is applied to a flat plate rather than to the target itself, so obtaining a uniform surface is no longer a problem. The coating processes for the blackbody and for the background plate are now identical, yielding consistent emissivity. Reflective targets can be fabricated with unprecedented detail - even halftone images of scenes can be created.

Radiance drift

There is yet another problem with the traditional blackbody/collimator/emissive-target system, this one a bit more subtle. To understand this problem, it is important to note that FLIRs do not really detect temperature differences (Δt), but rather radiance differences (ΔW). Since radiance is not a linear function of temperature, a given ΔT will not always produce the same ΔW. The ΔW will change if the temperature of the target changes, even though the ΔT is held constant. In the test system of Figure 1, the temperature of the target changes, even though the ΔT is held constant. In the test system of Figure 1, the temperature of the target drifts with room temperature, resulting in an unstable ΔW. This effect is small and has largely been ignored in laboratories where the room temperature is fairly constant, but has become more important as FLIRs have become more sensitive. It can also be significant in field testing, where ambient temperature is not controlled. Some advanced blackbody controllers have built-in correction algorithms to reduce these errors. A less effective solution is the use of water cooling to control target temperature. These targets are cumbersome to use and are highly nonuniform. The nonuniformities can be resolved by most FLIRs.

The new Reflective-Target collimator provides a solution to this difficult problem. The ambient plate is replaced with a second blackbody, as shown in Figure 5. The second blackbody controls the absolute temperature of the target image. The expense of two blackbody controllers can be eliminated through the use of a standard dual blackbody controller. A Reflective-Target collimator with dual blackbodies provides the ultimate in control and precision for the most demanding FLIR test applications.

The value of a constantly improving infrared imaging technology is universally accepted. FLIR technology is advancing beyond the built-in limitations of traditional IR test equipment. New testing technology - reflective targets, new collimator configurations and dual blackbody systems - can now support the latest FLIR advances.