An alternate method for performing MRTD measurements

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ABSTRACT

The Minimum Resolvable Temperature Difference test (MRTD) is one of the tests typically required to characterize the performance of thermal imaging systems. The traditional test methodology is very time intensive, requiring data collection at multiple temperatures and target frequencies. This paper will present an alternate methodology using a controlled blackbody temperature ramp rate. This allows selection of the temperature at which a target is determined "resolved" without stopping. Test results using the traditional method will be compared to test results using this alternate method.

Keywords: MRTD, IR, testing, temperature ramp, slew MRTD

1. INTRODUCTION

Minimum Resolvable Temperature Difference (MRTD) is one of the mainstays of IR imager performance testing[1]. Combining sensitivity and resolution measurements, the objective of the test is a plot of the minimum temperature difference necessary for an observer to resolve a specific spatial frequency. This plot line divides the space of temperature vs. spatial frequency into areas in which observers can resolve a target image and where they cannot (Figure **1**)

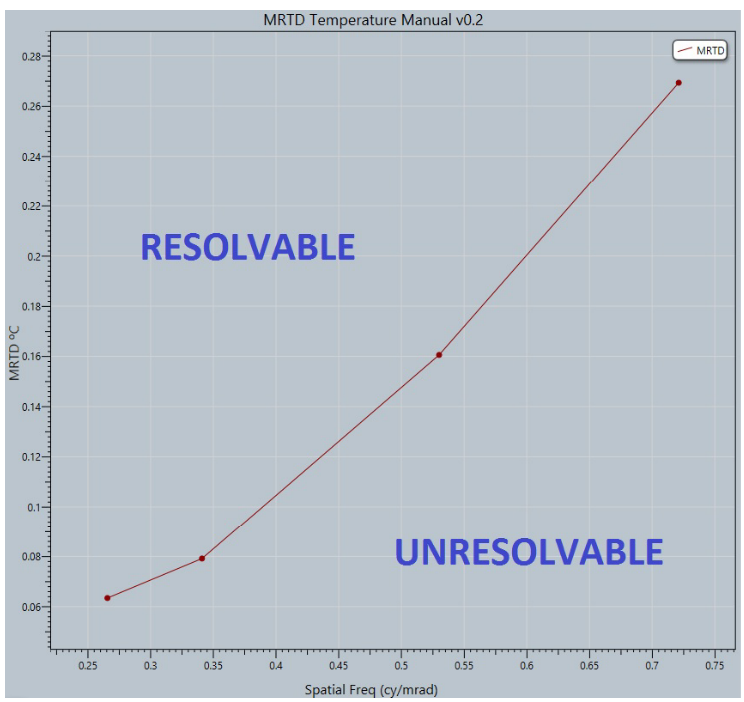

Figure 1 MRTD plot, temperature vs. spatial frequency

The test is subjective, meaning that a human observer is used to determine whether a specific target can be resolved. The traditional setup consists of the unit under test (UUT) looking at a 4-bar target through an optical system that allows the

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spatial frequency to be well defined. The 4-bar target is a thin piece of metal with 4 bars etched away so that the observer can see through the target to a temperature source (typically a blackbody) sitting behind the target (Figure **2**). A temperature control system measures and sets the temperature of the blackbody relative to the temperature of the target allowing a differential temperature to be set up between the observed bars and the surrounding area. This temperature difference can be controlled by the observer.

The traditional method of conducting an MRTD allows the operator to change the temperature difference set point, then wait for the temperature to stabilize, and then wait for the operator to decide whether the 4 bars are resolvable in order to move on to the next step or the temperature difference needs to be changed and all of these steps repeated.

This method is often the bottleneck of modern testing because of the amount of time it takes to conduct the test compared to most objective (and automated) data collection and analysis. The time is dependent on the speed of the blackbody and target temperature measurement, the temperature slew rate of the blackbody, and the amount of time it takes for the blackbody to achieve uniform distribution of the temperature (no local hot spots). The other critical time component is the time it takes for a human observer to decide whether the target is resolvable. Modern blackbody controllers can accurately measure temperatures very quickly. And typically, a 4-bar target covers a very small surface area of a blackbody, so the time to achieve uniformity is very low. The strongest time dependencies are based on the time it takes to change the temperature of the blackbody and for the operator to decide whether the target is resolvable.

Some laboratories have gone to great lengths in order to speed up this step in testing a UUT's performance; including having multiple blackbodies stabilized around the temperatures of interest, and changing the test methodology to use simpler pass/fail criteria at fixed temperature differences and spatial frequencies. These methods may be cost effective based on production requirements (unit quantities and staffing) but do not fully characterize a device.

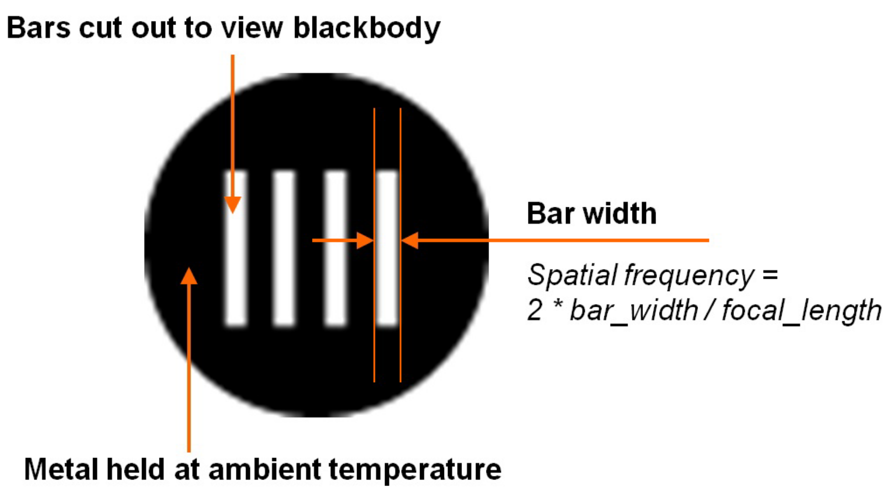

Figure 2 A 4-bar target sets the spatial frequency and uses a blackbody to set temperature difference

An alternative method has been discussed and is used at some laboratories. This method establishes a fixed rate of temperature change on the blackbody. The temperature ramps between a value that is below the resolution threshold to a value that will be well above the expected MRTD. The observer is looking for the moment when the 4-bars are fully resolvable, at which point they trigger a measurement of the temperature difference. In the same way as the manual method, this measurement is performed for both a positive and negative temperature difference and the average of the two is calculated. This is the measured MRTD for the spatial frequency of the target.

Santa Barbara Infrared, Inc. (SBIR) manufactures a line of high performance, high accuracy, extended area blackbodies for use in MRTD measurements. Customers have successfully used these bodies in their traditional MRTD measurements for decades. Due to customer requests, we are introducing the Smart Slew option to our Infinity Blackbody Controller[2]. This control feature lets an operator set the rate of temperature change for the blackbody. This rate change is highly accurate and maintains uniformity during the temperature ramp. It specifically supports this slew based MRTD methodology.

SBIR decided that we needed to conduct testing of our own in order to see the efficacy of this alternate MRTD method as compared to the more traditional method, and to develop guidelines and parameters that best achieve accuracy, repeatability, and speed. Up to now, we've seen no studies which report these findings. This study is a first look at this development and our initial findings.

2. METHODS & EQUIPMENT

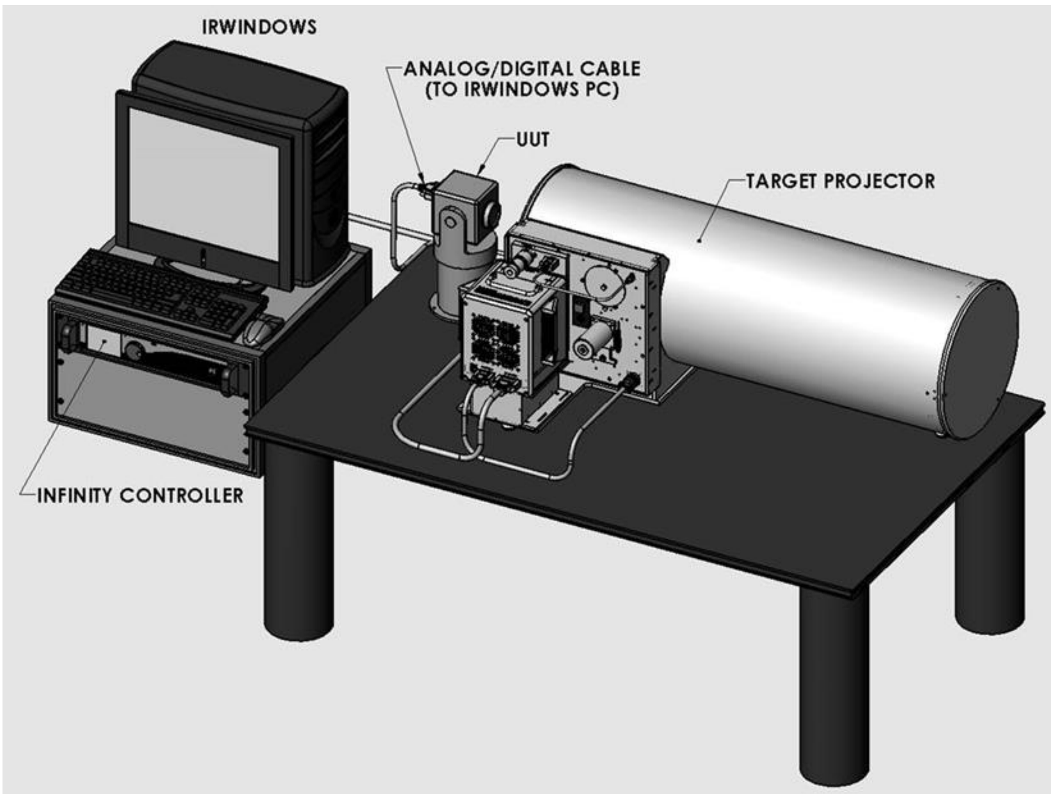

Figure 3 Standard IR test bench configuration

SBIR has a standard test bench configuration used for Electro Optical device testing (Figure **3**). The target projection system consists of collimating optics, a target wheel, and blackbody configured to project the 4-bar targets to the UUT. The blackbody controller is connected to the computer and the UUT is connected to a frame capture device that is also connected to the computer. This configuration allows the IRWindows 4 test software to control the blackbody and target settings to the UUT, and capture the resulting output from the UUT. Then the IRWindows package can analyze the image and calculate important figures of merit for the UUT.

For this study, the Manual MRTD method included with IRWindows was used for the traditional MRTD test[3]. A new procedure (Slew MRTD) was developed in IRWindows to take advantage of the Smart Slew feature of the SBIR Infinity Blackbody Controller. This test was used to measure the performance of the temperature ramping method of MRTD. Details of the algorithm are described at the end of this section.

The collimator has a 30 inch focal length and a 6 inch exit aperture, and it has a 4 inch extended area blackbody. Four targets were used with characteristics shown in Table **1**.

Table 1 Targets used in the study

Step	*Bar Width (in)*	*Spatial Frequency (cyc/mrad)*
1	0.0565	0.2655
2	0.0440	0.3409
3	0.0283	0.5301
4	0.0208	0.7212

For the UUT, we used an IR Cameras IRC912 closed cycle camera with a 1280x1024 nBn FPA. It had a 25 mm lens which gave us an effective Nyquist frequency of 1.042 cyc/mrad. There isn't an integral display in the camera, so digitally captured images are displayed at real time frame rates on the computer screen using the IRWindows Image Viewer. The camera has a GigE communications channel which was connected to a dedicated network card, minimized any potential camera lag.

Three observers were selected, two of which had never conducted an MRTD and the third had experience in lab and field MRTD testing (traditional).

2.1. Manual MRTD Algorithm

For each target in the test set, the following steps occur:

- Select the target and set the temperature to 0 degrees difference
- The observer changes the temperature using the arrow key on the keyboard while looking at the real time target image on the computer display. The temperature of the bars is positive compared to the target background (ambient) temperature. These are referred to as white bars
- When the observer has decided that the minimum temperature difference has been set to resolve the bars, the *Accept* button is selected (either the *A* key on the keyboard or a mouse click on a display button). This temperature difference is recorded.
- The blackbody temperature is set to 0 degrees differential. The target is not changed.
- The observer once again changes the temperature difference using the arrow keys on the keyboard. However, this time the blackbody temperature is set below the ambient temperature of the target so that the bars appear darker than the rest of the target. These are black bars.
- This time, when the observer accepts the minimum resolvable temperature difference, the temperature results are stored for the selected target and the test can move on to the next target.

2.2. Slew MRTD Algorithm

For each target in the test set, the following steps occur:

- Select the target and set the blackbody temperature to 0 degrees differential
- The observer clicks on a button that starts the blackbody temperature slewing in a positive direction (for white bars). For each target frequency, a separate temperature slew rate was applied.
- When the observer is finally able to resolve the target (looking at the image on the computer screen), the *Accept* button is selected (either the *A* key on the keyboard or clicking on the display button). This temperature difference is recorded.

- The temperature is set to 0 degrees differential. The target is not changed.
- The observer clicks on a button that starts the blackbody temperature slewing in a negative direction (black bars).
- This time, when the observer is able to resolve the target and selects *Accept*, the results for this target are stored and the test moves on to the next target.

3. MEASUREMENTS

All three observers were given a short training session by one of the authors (Jack Grigor) on the MRTD measurement methods and the criteria for determining resolution of the target. The trainer was not one of the observers. The agreed upon criteria for the lab tests were that 4 bars must be distinct, and 75% of the total area of the bars must be identified.

Tests were conducted over 5 days and the observers were given the option to alternate between Manual MRTD and Slew MRTD tests, or to do a batch of one type of test followed by a batch of the other. Both methods were used, but this parameter was not used in the analysis.

In addition to recording the temperature differences at which the observers accepted an MRTD value, the tests also recorded the elapsed time for performing the test. There was only one test in which an interruption significantly impacted the execution time of a test, and that result was removed from the analysis

4. RESULTS

Twenty nine tests were conducted over the 5 days of testing. For each observer, the standard deviation of the measurements on each spatial frequency was calculated and shown as a percentage of the average reading in Table **2** (Manual MRTD) and Table **5** (Slew MRTD). These results can be compared to the results from previous MRTD studies and shows that the variation in values is within expected MRTD norms[5].

From these tables we can also see that there isn't a strong difference in variation based on the slew method and the manual method. Some slew readings for some observers are less consistent than their manual counterparts, and the readings on other spatial frequencies for the same observer are more consistent. The only consistent bias is that the trained observer (observer 3) had a much smaller deviation on all readings than the untrained observers.

Table 2 Standard deviation as a percentage of average reading (Manual MRTD)

Observer	*0.02655 cyc/mrad*	*0.3409 cyc/mrad*	*0.5301 cyc/mrad*	*0.7212 cyc/mrad*
1	18.7%	21.3%	11.6%	11.3%
2	22.2%	13.7%	20.9%	11.0%
3	10.0%	10.4%	7.5%	7.0%

Table 3 Standard deviation as a percentage of average reading (Slew MRTD)

Observer	*0.02655 cyc/mrad*	*0.3409 cyc/mrad*	*0.5301 cyc/mrad*	*0.7212 cyc/mrad*
1	17.6%	24.4%	21.2%	24.4%
2	18.9%	11.7%	12.0%	22.2%
3	3.8%	6.6%	9.7%	10.5%

The next interesting result is a comparison of the MRTD measurements based on manual methods to the measurements from the slew method. For this calculation, we took the average slew measurement minus the average manual measurement and divided by the average manual measurement as shown in Table **4**.

Table 4 Percentage change from the manual measurement to the slew measurement

Observer	*0.02655 cyc/mrad*	*0.3409 cyc/mrad*	*0.5301 cyc/mrad*	*0.7212 cyc/mrad*
1	11.9%	15.4%	13.1%	23.1%
2	0.8%	13.8%	8.7%	22.3%
3	4.3%	9.3%	0.1%	11.2%

The values from this table vary, but there are 3 general trends. First, and most striking, is that the slew test clearly biases to the positive. There were no negative changes. This seems to indicate that there is a lag in the test methodology between the moment when an observer accepts the resolved image and when the temperature difference is recorded.

The second possible trend is that the error somewhat increases with increasing spatial frequency. This is by no means consistent even within a single observer's error values, but for all observers, the biggest error was the highest frequency. This may be related to the recording lag already indicated.

And third, observer 3, the trained observer, showed consistently smaller changes between the measurements made using the two methods. The reason isn't obvious, but may be related to the smaller deviations for this observer as shown in measurement analysis.

Table 5 Test duration statistics

	Manual	*Slew*
Average (sec)	607	454
Maximum (sec)	1241	590
Minimum (sec)	350	358
Standard deviation (sec)	168	64
% deviation to average	27.7%	14.0%
Overall improvement in execution time		**25.2%**

The final analysis looks at the time difference in executing the two test methods. The average of all the tests is shown in Table **5** along with the maximum, minimum, and standard deviation of the times. The obvious improvement is the overall execution time; the slew method shows a 25% improvement over the manual method. However, additional review shows that the slew method also gives more consistent and predictable execution times. The manual method showed a wide variation in test durations, from just less than 6 minutes to over 20 minutes. The slew method only varied from 6 minutes to under 10 minutes. This will be discussed further in the conclusions.

One other result surfaced when conducting informal interviews with the observers after the testing. All three observers indicated that there was a significant reduction in stress levels when conducting the Slew MRTD. Something about the deterministic nature of the test, and the instant, single point resolution decision for each step was easier than the unlimited time and repeated resolution decision necessary when running the Manual MRTD test. This wasn't at all anticipated, but is significant when so much of the test is subjective and dependent on the frame of mind of the observer.

5. CONCLUSIONS

The goal of this study was not to make the definitively analysis of the Slew MRTD method, nor to determine the optimal improvement that the method provides. Instead, we conducted these tests to get a general idea of the possible improvements, see what problems might arise, and make improvements to the algorithm based on feedback from observers actually performing the test.

To that end, we saw significant speed improvements, but not to the degree we expected. The 25% speed improvement is enough to motivate further development of the algorithm but isn't a call to arms for universally adoption.

We have several paths for further study and implementation. First, the observers have suggested several improvements to the user interface. And. although measurement variances are within expectations, the data indicates that investigating lag issues will improve repeatability and accuracy.

Overall, based on the current results, we recommend that if you are planning to conduct a large number of MRTD tests, then the speed improvement, the deterministic nature of the test duration, and the reduced stress level on the observers all recommends using a slew method. However, if you are only running infrequent MRTD testing and already have procedures in place, the speed improvement doesn't justify the cost of developing a new set of in-house procedures.

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