FUDIT

System for testing fused imagers

Fig. 1. Photo of FUDIT150 test system

1 Basic information

Fusion imaging systems offer increased surveillance capabilities due to fusion of thermal image with classical visible image. The fusion systems are typically built using a multi-sensor imaging system composed with a thermal imager and a visible imaging camera (night vision device, visible camera). Near perfect alignment of these two types of images is one the biggest challenges in design of fusion imaging systems. It is quite common to find on market fusion imager that generate output fused image with significant alignment defects: thermal image of targets of interest does not overlay exactly with visible image of the same targets or image processing software is too slow.

Testing and alignment support of fusion imagers at design stage is challenge for typical laboratory test systems built as image projectors. The typical test systems can project both thermal image and visible image of simulated reference target but only separately. These two images cannot be projected at the same time because typical test systems for testing multi-sensor imagers used two mechanically exchangeable radiation sources: differential blackbody and visible light source.

2 What is FUDIT?

Since 2017 Inframet manufactures DT systems for testing thermal imagers and VIS-NIR cameras that work as image projectors of thermal/visible images generated using special dual color blackbody coded DCB blackbody. The latter radiation source is built by combining modified (different emitter) differential area blackbody with a visible light source. Therefore DT systems do project both thermal image and visible image at the same time and can be used to support boresight of fused imagers (alignment of thermal channel with visible channel) at design stage. However, there is a significant limitation of such DT systems for testing fused imagers. These test systems use targets manufactured from opaque metal sheet with holes of proper shape to simulate reference target in both thermal band and visible band. This design means that DT can project thermal images of regulated contrast but can project only visible images of 100% positive contrast (bright target on black background). This is a non realistic scenario because targets in visible band are typically of low contrast and this difference can negatively influence accuracy of testing/alignment of fused imagers.

FUDIT is a specially modified DT system to be optimized for testing fused imagers that enables projection at the same time of two types of images (thermal image and visible image) of regulated contrast. In this way realism of projected scenery is improved comparing to typical DT systems.

3 What is target contrast?

Contrast of reference target is a ratio of difference between radiation intensity of simulated target and radiation intensity of simulated background to radiation intensity of the background. In case of thermal image the contrast is approximately equal to ratio of difference between temperature of simulated target and temperature of simulated background to background temperature. In case of visible image the contrast is approximately equal to ratio of difference between luminance (perceived brightness) of simulated target and luminance of simulated background to background luminance.

Contrast of projected image of the reference target can differ from original target contrast if cameras uses some image processing tools (contrast inversion, contrast enhancement, contrast gain/reduction) available for both VIS-NIR cameras and thermal imagers. However, it is typically assumed that basic mode of work of the imager is when original contrast is kept intact or changes are minimal. Next, perfect test system should be able to project to tested fused imager images of the reference target of the same contrast as contrast of original targets met during real work.

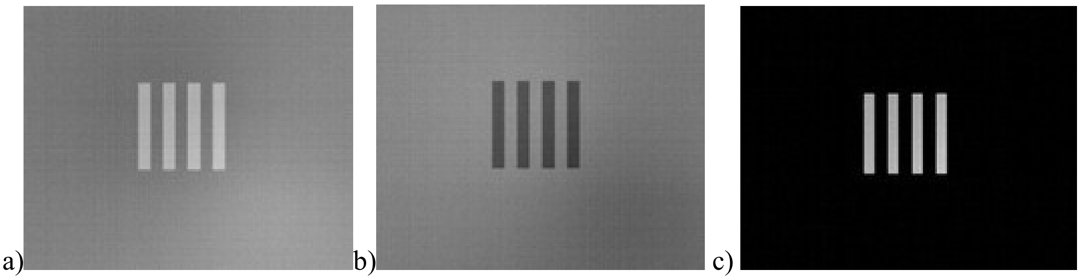


Fig. 2. Images of three targets of different contrast: a)thermal target of medium positive contrast, b)thermal target of medium negative contrast, c))visible target of high (100%) positive contrast

4 How FUDIT is built?

FUDIT is built from a set of modules:

1. CDT-F off axis reflective collimator (typically CDT15120HR- https://www.inframet.com/Data_sheets/CDT.pdf)
2. MRW-2D rotary wheel https://www.inframet.com/Data_sheets/MRW8.pdf
3. DCB-2D-SEM2 dual color blackbody (including SEM2 light source) https://www.inframet.com/Data_sheets/DCB.pdf
4. Set of targets (set of 4-bar targets, edge target, cross target, multi point target)
5. LS-COL light source (inside the collimator)
6. XNAS-5 positioning stage (for tested fused imager) -option XMAS-5 stage for WFOV imagers
7. TCB Control program - control of temperature of DCB color blackbody
8. SEM Control program - control of luminance of DCB color blackbody
9. SUB-T test program - support for subjective MRTD measurement
10. TAS-FUS test program - support for semi automatic measurement of objective parameters of tested fused imager
11. BOR test program - support for measurement of boresight errors
12. DPM diopter power meter (optional for optical imagers)
13. HEC camera to simulate human observer (optional for optical imagers)

This list of modules shows that FUDIT is actually modified DT system. The new/modified modules are:

1. Special version of CDT reflective collimator where a light source can be inserted
2. LS-COL light source to simulate background of reference target located at collimator focal plane
3. XNAS-5 stage for precision angular positioning of tested fused imager.

It should be noted that angular size of image projected by FUDIT depends on focal length of the collimator. typically modified CDT15120HR collimator of 150mm aperture and 1200mm focal length is offered but different collimators can be delivered.

5 How FUDIT works?

FUDIT works as image projector capable to project image of a reference target in two spectral band (MWIR-LWIR and VIS-NIR) and to regulate contrast of projected images.

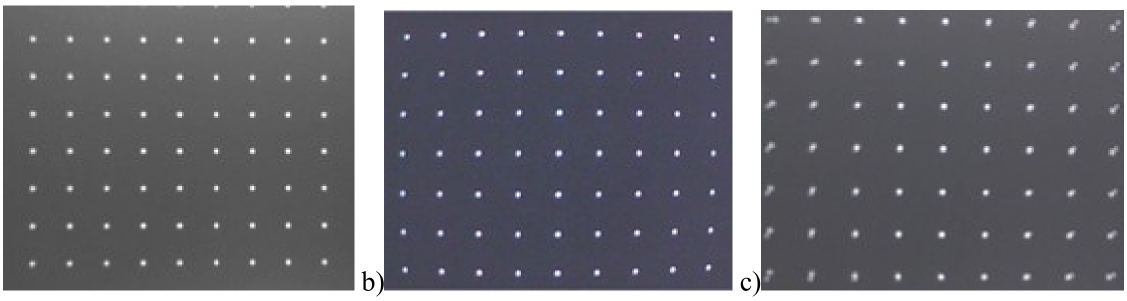
In detail, FUDIT project images of typical targets used in testing thermal imagers (4-bar target, edge target, cross target) and fusion specific target (multi-pinhole target). The target plates are manufactured by cutting holes in thin

metal sheet in required shapes and later coated using high emissivity coating. In this way it actually transmissive hole on a opaque background.
Apparent target temperature is regulated by changing temperature of blackbody emitter in DCB-2D-SEM2 dual color blackbody. Apparent temperature of target background is not regulated and is equal to ambient temperature of target plate or rotary wheel. Contrast of projected image can be both positive or negative because blackbody temperature can be higher or lower comparing to ambient temperature.
Apparent target luminance is regulated by changing luminance of light emitter in DCB-2D-SEM2 dual color blackbody. Apparent luminance of target background is regulated by changing luminance of LS-COL light source. The system is designed in such a way that target luminance is always higher or equal to background luminance. Therefore contrast of projected image in VIS-NIR band can be regulated from 0 to 1 and is always positive.

6 Alignment defects

Near perfect alignment of two imaging channels the biggest challenge in design of fused imagers. The aim of designer is to achieve situation when thermal image of targets of interest does precisely overlay with visible image of the same targets. It should be noted that image shift at only one pixel level is noticeable and is treated as significant defect. Therefore sub-pixel alignment accuracy is needed in case of near perfect fusion imagers.
Practically it is common situation in many fused imagers to see excessive blurring of scenery of interest in center part of output fused image and noticeable separate images of small targets in outer of the same image.

Reasons for such a situation depends slightly on type of fused imager: optical fused imager or electronic fused imager. In case of the first type, fusion is done by overlay of two optical images generated by night vision channel and thermal imaging channel. Non perfect aligning is due to some angle between optical axis of both channels, image rotation difference, image magnification difference, and image distortion difference. The aligning errors can be minimized by selection of optical objectives (night vision objective and thermal objective) of very similar optical parameters and by precision aligning of the imaging sensors relative to optical objectives.
Situation in case of electronic fused imagers (thermal imaging channel and VIS-NIR imaging channel) looks better. The sources of of alignment defects are practically the same but these defects can be at least partially corrected by some digital image processing. However, high speed fusion of two electronic images of dynamic targets located at different distances is still a big challenge.



a) b) c)

Fig. 3. Image of multi pinhole target recorded by an exemplary fused imager: a)thermal channel image, b)visible channel image, c)fused image with noticeable shift between pinhole images generated by two channels

7 Characterization of fused imagers

There are no internationally accepted standards that regulate testing and characterization of fused imagers. In such a situation Inframet proposes it own test methodology based on experience from practical tests of such imagers in field condition.
The methodology of testing of fused imagers proposed by Inframet is based on idea that parameters of fused imagers can be divided into three groups:

1. typical parameters that characterize thermal imagers to be used to characterize thermal channel
2. typical parameters that characterize VIS-NIR cameras (night vision device) to be used to characterize visible channel
3. parameters to be used to characterize fusion of thermal image with visible image.

In Inframet opinion fusion defects can be divided into two main groups

1. noticeable separate images of targets (typically only in outer of the fused image as seen in Fig. 3)
2. noticeable blurring of fused image (Fig. 4).

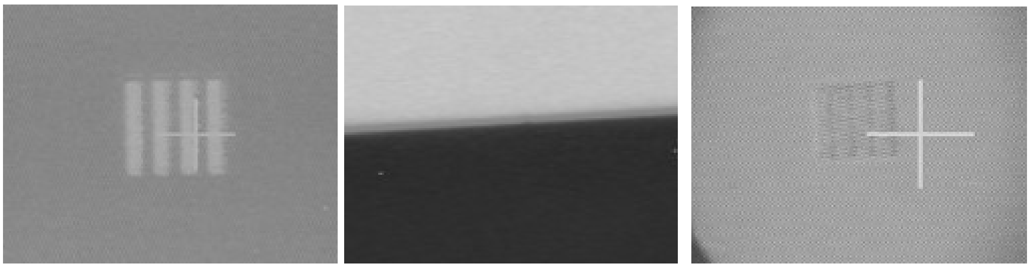


Fig. 4. Exemplary fused images with noticeable defects: a)image of static 4-bar target with noticeable blurring, b)image of edge target with noticeable edge shift, c)blurred image of dynamic 4-bar target due to time delays of thermal image relative to visible image

The first type of fusion defect can be measured as local angular shift between two images (thermal relative to visible). Measurement can be done manually by marking of centers of pinhole images or by semi-automatically when software automatically detect centers of two pinholes and calculates distance.

In order to characterize of image blurring due to fusion quality Inframet proposes measurement of two new parameters:

1. normalized fusion MRTD (coded NFMRTD),
2. normalized fusion MTF (coded NFMTF).

Normalized fusion MRTD is a ratio of MRTD of thermal channel to MRTD measured using fused image generated by both channels. Normalized fusion MTF is a ratio of MTF measured using fused image to MTF of thermal channel:

$$NFMRTD = \frac{Thermal\,MRTD}{Fusion\,MRTD} \qquad NFMTF = \frac{Fusion\,MTF}{Thermal\,MTF}$$

Both NFMRTD and NFMTF equal to one in case of fused imager capable to do perfect fusion.

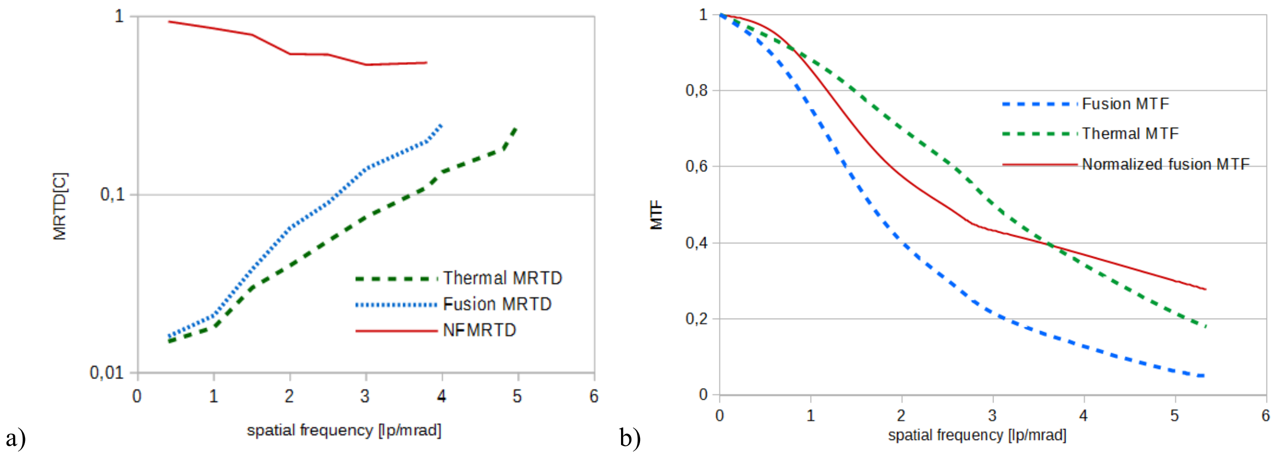


Fig. 5. Measurement results of exemplary fused imager: a)NFMRTD, b)NFMTF

8 Test capabilities

FUDIT offers following test capabilities:

1. support for aligning of two channels of fused imagers
2. measurement of parameters to characterize thermal imaging channel: MRTD, MTF, SiTF
3. NETD, FPN, nonuniformity, distortion, FOV
4. measurement of parameters to characterize visible imaging channel: MTF, distortion, FOV
5. measurement of parameters to characterize quality of image fusion: boresight errors for different parts of image, NFMRD, NFMTF.

Support for aligning of two channels of fused imagers is offered by projecting images of reference targets that are visible for both channels of tested fused imager. Boresight error between two channels are visible in form of shift between two images. BOR software enable precision measurement of such image shift.

9 FUDIT limitations

Off axis reflective collimators enable to project images of relatively narrow FOV (below about 4º). In detail, angular size of projected image for different collimators is shown in Table 1.

Table 1. Parameters of collimators used as projectors for FUDIT

Collimator type	Collimator aperture [mm]	Collimator focal length [mm]	Collimator FOV [º]
CDT15120HR	150	1200	3º
CDT12100HR	120	1000	3,3º
CDT660HR	60	600	4º

Practically it means that images projected by FUDIT can fill fully or most part of FOV of tested fused imagers only in case of long/medium range fused imagers of narrow FOV. FUDIT can still be used for testing fused imagers having FOV several times bigger than collimator FOV (typical situation when testing thermal imagers). The problems can occur in case of fused imagers having visual channel always working in automatic gain control. Such imagers can still be tested but contrast regulation of visible target will not work properly.

10 FUDIT versions

FUDIT test systems are modular test systems that can be delivered in form of different versions of different configurations, test capabilities and price.

There are several criterion to be used to clarify version of FUDIT:

a)collimator aperture (and indirectly focal length)

b)type of tested fused imager.

Available collimators are listed in Table 1. FUDIT150 means collimator built using collimator of 150mm aperture. FUDIT design is optimized for testing electronic fused imagers where gain/brightness can be manually controlled Only for this type of fused imager FUDIT can project imagers of low contrast targets for most realistic tests of visible channel. However, boresight and basic of optical fused imagers can be carried out too.

Table 2. Codes of FUDIT system depending on range of tested types of fused imagers

Code	Test range
EL	only electronic fused imagers
OP	only optical fused imagers
ELOP	both electronic and optical imagers

If testing optical fused imagers is requested Inframet delivers additionally DPM diopter power meter, H2EC dual channel camera. Test software is modified, too.

Example coding: FUDIT150EL means FUDIT test system built using collimator of 150mm aperture and capable to test only electronic fused imagers.

11 Summary

FUDIT is the first commercially available system for boresight and expanded testing of fused imager presented on world market. It enable precision performance testing, especially in case of medium/long range fused imagers.

Version 1.3

CONTACT: Tel: +48 226668780 Fax: +48 22 3987244 Email: info@inframet.com