IR targets

Modules of systems for testing thermal imagers

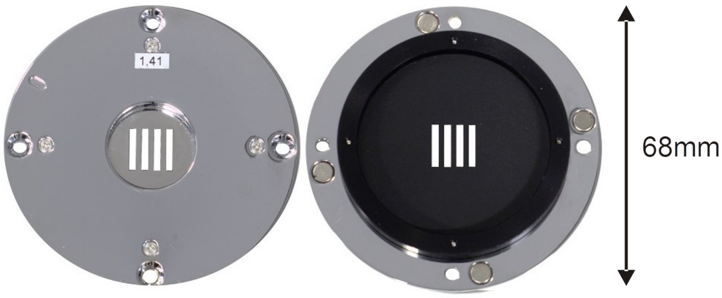


Fig. 1. Photo of an exemplary typical IR target seen from two sides

1 Types of targets

Targets are modules that can create image of reference patterns needed when testing electro-optical imaging systems. The targets manufactured by Inframet can be divided into two groups:

1. Passive targets
2. Active targets.

The passive targets need to be irradiated by a uniform beam of light generated by blackbodies or calibrated light sources in order to create images of reference image patterns. These targets are typically small modules of bigger test systems. The passive targets do not need electric power for proper work.

The active targets create images of reference image patterns due to their own thermal radiation or due to reflected light emitted by sources typically met in human environment. These targets are typically big stand alone modules that need electric power for proper work.

The passive targets can be divided according to application on three groups:

1. Infrared targets (IR targets),
2. Visible targets (VIS targets),
3. Night vision targets (NV targets).

The IR targets are used for testing thermal imagers operating at MWIR-LWIR spectral band. VIS targets are used for testing color VIS cameras, monochromatic VIS-NIR cameras, or VIS-SWIR cameras operating in VIS-SWIR spectral band. NV targets are used for testing nigh vision devices operating in VIS-NIR spectral band. These three group of targets differ due to manufacturing technology even if both VIS targets and NV targets work in similar spectral band.

2 How IR targets are made?

IR targets are metal plates having holes in required shape that create image of reference pattern due to radiation passing through the holes and light emitted/reflected by rest of target plate. IR targets are typically small (plates below 100mm) but technically bigger IR targets can be manufactured too.

In detail, IR targets are manufactured by creating precision holes of different shapes (4-bar, circle, cross, semi-moon (semi-square), triangle and so on) in thin metal sheets. The surface of the metal sheet can be coated using high emissivity coating (case of emissive IR targets) or kept polished to achieve high reflectivity (case of reflective IR targets). Both types of IR targets will generate the same test results if used properly.

Typical IR target is built from a set of parts: thin metal sheet with holes, positioning ring, metal plate to fit to holes in rotary wheel, connectors (Fig.1).

3 How IR targets work?

The IR targets are typically inserted to holes in motorized rotary wheels used in a series of Inframet test systems for testing thermal imagers or multi-sensor imaging systems based on a reflective collimator: DT, TAIM, DTR, and MS system [Fig.2]. The rotary wheel with targets is located at focal plane of a collimator that simulate infinity distance targets. The TCB blackbody is put behind such a target and the tested thermal imager sees a "target" of shape determined by the holes on the uniform background. The apparent temperature of this "target" is equal to blackbody temperature. Temperature of the background of the "target" is equal to temperature of the metal sheet (case of emissive IR targets) or is equal to temperature of internal collimator blackbody (case of reflective IR targets).

Most of Inframet systems for testing thermal imagers use small size (68 mm diameter) target plates fixed to

MRW-8 rotary wheel. Bigger targets are used in case of systems built using collimators of long focal length (over 2m) and then can be fixed on wheels having bigger holes.

The IR targets can be also fixed to small manual target sliders and attached to TCB blackbody located on CDT collimator. This is the case of SIM and MIM test systems.

The IR target typically fills only part of FOV of tested imager in all earlier listed test systems based on reflective collimator as image projectors.

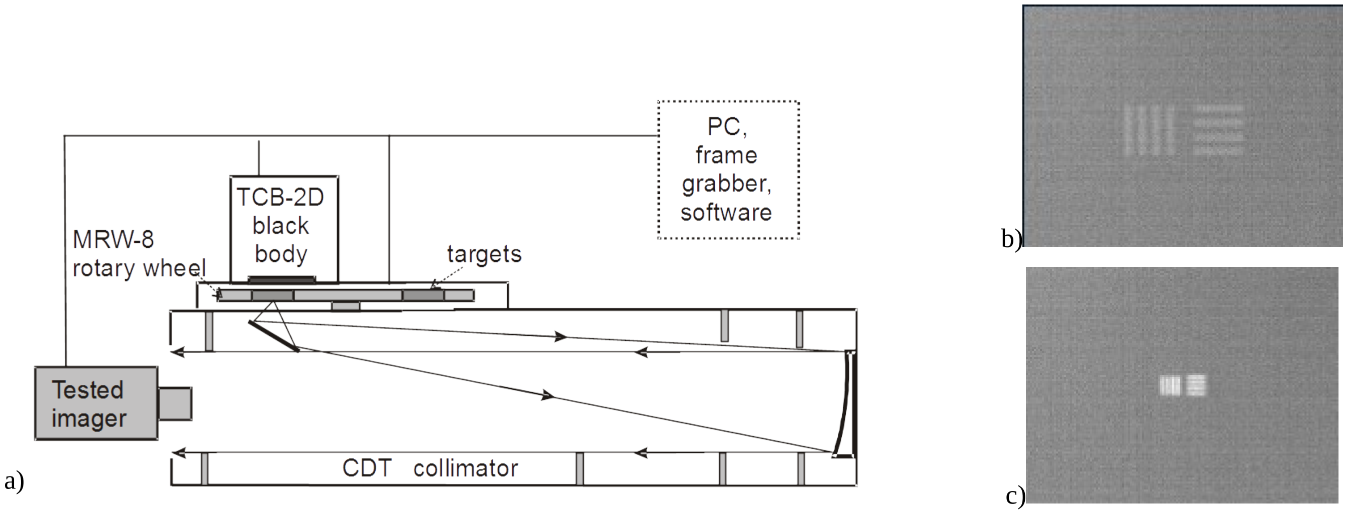


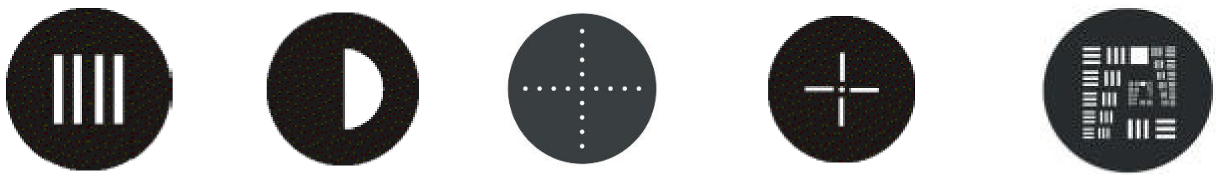
*Fig. 2. System for testing thermal imagers: **a)** block diagram, **b)** image of large 4-bar target of temperature difference equal to 0.3ºC, **c)** image of large 4-bar target of temperature difference equal to 1ºC.*

4 Shapes of IR targets

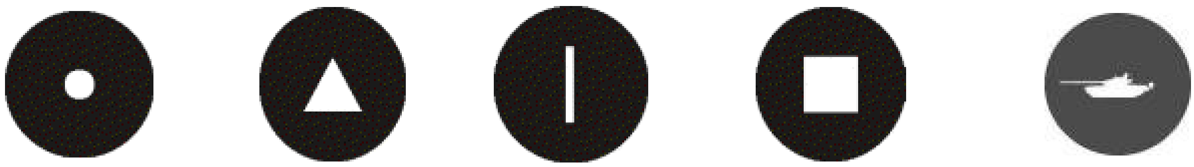
INFRAMET manufactures IR targets that can generate thermal images of twelve different patterns: single 4-bar, semi-moon, dot cross, aim cross, IR USAF1951, pinhole, triangle, slit, square, silhouette. Details on typical dimensions of these targets are presented in Section 13 of this data sheet.

Table 1. Patterns of IR targets manufactured by Inframet

a)Four-bar b)Edge c)Dot cross d)Aim cross e)IR USAF 1951



f)Pinhole g)Triangle h)Slit i)Square j)Silhouette



Applications of targets in Table 1 are presented below.

Most popular targets:

1. Four-bar targets are needed to measure MRTD (minimum resolvable temperature difference) function.
2. Edge target is typically used for MTF measurement.
3. Dot cross target is used in procedures to measure FOV or distortion.
4. Aim target is used in boresight tests.
5. IR USAF1951 target is used in applications that require fast evaluation of resolution of tested thermal imager.

Other targets are less popular but have some applications areas.

1. A series of pinhole targets is needed to measure MDTD (minimal resolvable temperature difference) function.
2. A series of triangle targets is needed to measure TOD (Triangle Orientation Discrimination) function (alternative to MRTD).
3. A series of slit targets is needed to measure SRF (slit response function) - useful to evaluate measurement thermal imagers.
4. Square target was needed to measure NETD of thermal imagers using old methods several decades ago. Nowadays it is rather obsolete because NETD can be measured without need to any target.
5. Silhouette targets (example tank pattern) enables simple yes/no test of detection/recognition of targets of specified angular size (distance).

IR targets

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5 Emissive targets versus reflective targets

Emissive IR targets can be considered as classical well known targets that are manufactured by coating metal sheet with hole by diffusive black paints or by carbon deposition in vacuum chamber. Reflective targets market are manufactured by polishing metal sheet to achieve high reflectivity in infrared band.

It should be noted that the emissive targets has one blackened side of high emissivity (the side seen by tested thermal imager) and the second polished high reflectivity side (the side from blackbody to reflect blackbody radiation). In case of reflective targets both sides are polished and have high reflectivity.

The emissive targets are classical solution widely used but have two big disadvantages:

1. Low cost coating using black paints of high IR emissivity is possible only for case of 4-bar pattern of bar width over about 0.2-0.3mm. If smaller bars are needed then it is necessary to use more expensive and time consuming carbon deposition in vacuum chamber.
2. It is necessary to use very thin metal sheets if ultra small pattern are precisely manufactured. If bar width of 4-bar target is to be 50µm then the sheet must be thinner than 50µm. The same rule for other bar patterns. The emissive targets made from metal sheets below about 0.1-0.2mm are thermally non stable. It means that temperature of such targets vary depending on air fluctuation and such variations are noticeable for high sensitivity thermal imagers of NETD below 20mK,
3. High emissivity black carbon coating obtained carbon deposition in vacuum chamber is soft and vulnerable to scratches. This softness reduces target life time of ultra precision emissive targets.

The biggest drawback of reflective targets is a fact that they need for proper work internal collimator blackbody of precisely measured temperature and this special demand generate some additional manufacturing costs of the collimator. However, they are simple for manufacturing and offer much better thermal stability comparing to emissive targets in case of ultra small patterns.

Due to these reasons Inframet typically offers

1. emissive targets for 4-bar patterns of bar width higher than about 0.25m (or circle diameter over 0.15mm),
2. reflective targets for 4-bar patterns of bar width smaller than about 0.25m (or circle diameter over 0.15mm).

However, it should be emphasized that Inframet has mastered technology of carbon deposition in vacuum chamber and can optionally manufacture emissive IR targets of four bar pattern as small as 0.02mm bar width.

Experiments carried out by Inframet have shown that systems for testing thermal imagers will generate practically the same results regardless of type of IR targets (emissive or reflective) if the targets are properly manufactured and used. This conclusion is supported by data from specialized literature on this subject [1].

Literature:

1. Paul Tristan Bryant, Jack Grigor, Stephen W. McHugh, and Steve White "Performance comparison of reflective and emissive target projector systems for high-performance IR sensors", Proc. SPIE 5076, Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XIV, (22 August 2003); https://doi.org/10.1117/12.498114

6 Number of needed four-bar targets

Four-bar pattern targets (single rotation or dual rotation) are the most popular IR targets. At least 90% of IR targets sold by Inframet are 4-bar targets. This popularity is due to fact that they are needed to measure MRTD (minimal resolvable temperature difference) - the most important parameter of thermal imagers.

In detail, MRTD is a function of a minimum temperature difference between the bars of the standard 4-bar target and the background required to resolve the thermal image of the bars by an observer versus spatial frequency of the target. This frequency is equal to inverse angular size of two bars of 4-bar target.

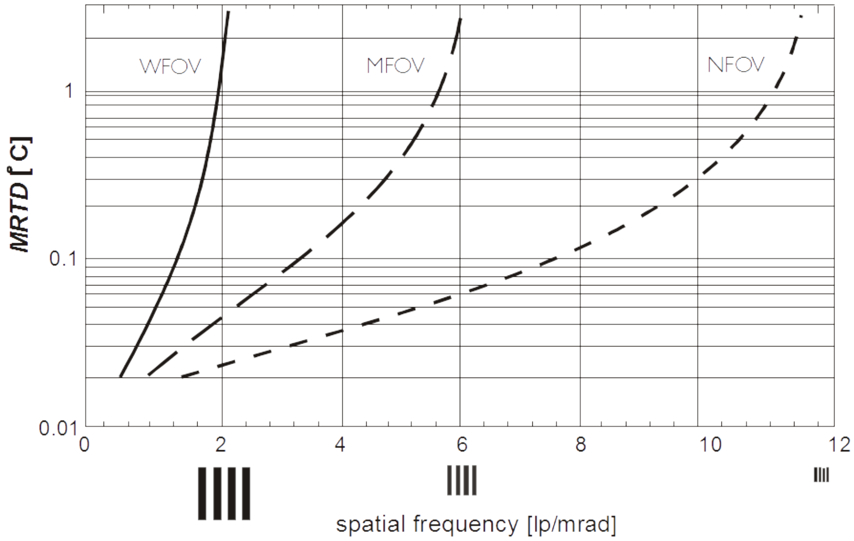


Fig. 3. MRTD of an exemplary thermal imager of three fields of view

MRTD function depends on spatial frequency and varies rapidly at high frequency range close to Nyquist spatial frequency of tested imager (Fig.3) that is equal to inverse angular size of a pair of pixels of thermal imager. In addition, MRTD functions of the same imager working at several FOVs is totally different. Further on, there are on market thermal imagers having myriads of different MRTD functions. Nyquist frequency of thermal imagers offered on market varies from about 0.05 lp/mrad to over 50 lp/mrad. Further on, MRTD function depends also on angular orientation of bars of 4-bar targets. In detail, there are two MRTD functions: horizontal MRTD measured using vertical 4-bar targets and vertical MRTD measured using horizontal 4-bar targets. Three decades ago, at age of scanning thermal imagers, there have been big difference between horizontal MRTD and vertical MRTD (horizontal MRTD was much better comparing to vertical MRTD). Now in case of staring thermal imagers the differences are typically small but still often are noticeable. This difference generates situation when MRTD is to be measured at more sampling points if both horizontal MRTD and vertical MRTD to determine accurate result.

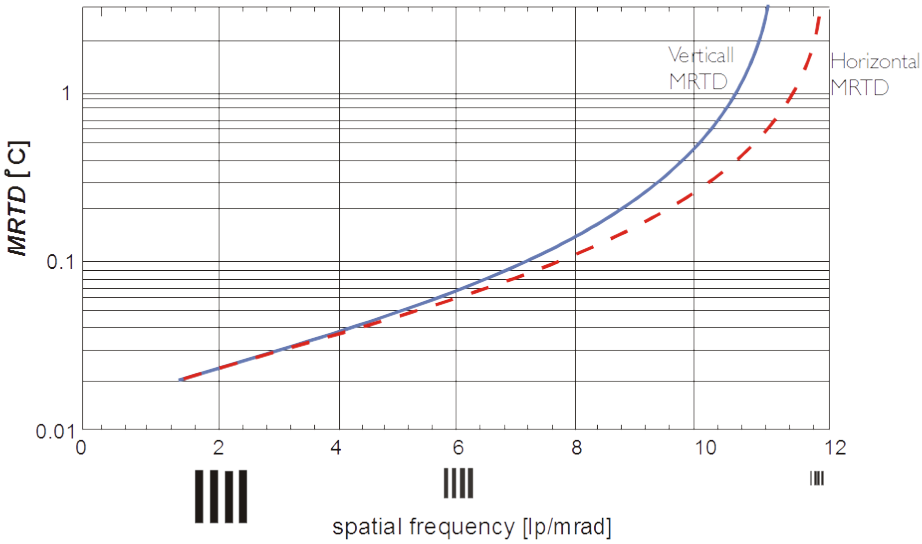


Fig. 4. Horizontal MRTD and vertical MRTD of an exemplary analog video thermal imager

The conclusion is that 4-bar targets having hundreds of spatial frequencies is needed to be sure that MRTD function of any thermal imager can be measured at high sampling density. In detail, if we assume that spatial frequency of 4-bar target is to increase by 3% from 0.05 lp/mrad to over 50 lp/mrad then 234 four-bar targets are needed. In reality IR targets with so high number of spatial frequency 4-bar patterns are extremely rarely needed. Typically a set of IR 4-bar targets in range from about 12 to 24 is considered as satisfactory for typical case of testing. Even for several thermal imagers of different Nyquist spatial frequency and having several FOVs. However, number of 4-bar targets of different spatial frequency can be reduced to 3-5 four bar pattern of different frequencies in case of thermal imager of single FOV, of known Nyquist frequency and similar vertical MRTD to horizontal MRTD. In such a case it is recommended to use following rules:

1. One 4-bar pattern of spatial frequency at low spatial frequency region,
2. One 4-bar pattern of spatial frequency at medium spatial frequency region
3. One 4-bar pattern of spatial frequency at spatial frequency equal to approximately 0.8 of Nyquist frequency,
4. One 4-bar pattern of spatial frequency at spatial frequency equal to approximately 0.9 of Nyquist frequency,
5. One 4-bar pattern of spatial frequency at spatial frequency equal to approximately Nyquist frequency.

In any case it is critical to determine accurately asymptotic part of MRTD function because this region typically determines ranges of detection, recognition, and identification calculated on basis of measured MRTD. Sometimes MRTD can be measured slightly over Nequist frequency and additional 4-bar targets are needed.

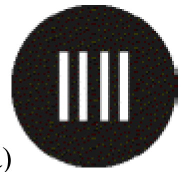
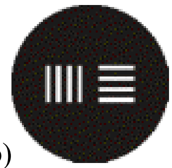
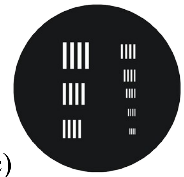
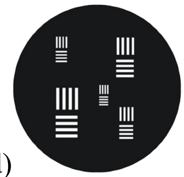
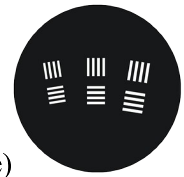
7 Types of 4-bar targets

Four bar target are manufactured in different forms that differ by number and rotation of 4-bar patterns. In detail, 4-bar targets can be divided into at least four groups (Table 2):

1. Single rotation 4-bar target,
2. Dual rotation 4-target,
3. Multi-size, single rotation 4-bar target,
4. Multi-size, dual rotation 4-bar target
5. Slanted, multi-size, dual rotation 4-bar target.

Single rotation 4-bar target is a target having a single 4-bar pattern of vertical or horizontal angular rotation. Dual rotation 4-target is a target having two 4-bar patterns of identical size but that differ in rotation by 90°. Multi-size single rotation 4-bar target is a target having several 4-bar patterns of different dimensions but of the same rotation. Multi-size dual rotation 4-bar target is a target having several 4-bar patterns of different dimensions and of two rotations. Slanted multi-size dual rotation 4-bar target is a special type of IR target defined earlier that will be discussed in detail later.

Table 2. Types of four bar targets

Single rotation	Dual rotation	Multi-size single rotation	Multi-size dual rotation	Slanted multi-size dual rotation
a) 	b) 	c) 	d) 	e) 

Definitions of MRTD presented in available standards and specialized literature refer to a case of single rotation 4-bar target. However, this type of 4-bar target is characterized by a several disadvantages.

1. Maximal number of spatial frequencies of 4-bar targets fixed to a rotary wheel is limited by number of holes in the wheel (typically not bigger than 12 holes),
2. Measurement of MRTD is slow if both horizontal MRTD and vertical MRTD are measured (after measurement of horizontal MRTD the 4-bar targets must be rotated by 90° and then measurement of vertical MRTD is to be carried out),
3. High cost of a set of single rotation 4-bar targets if dozens of spatial frequencies are needed.

Dual rotation 4-bar targets allow to shorten measurement time: no necessity to rotate the single rotation target.

Multi-size 4-targets can potentially shorten this time even more but additionally allow increase number of spatial frequencies of 4-bar targets fixed to a typical rotary wheel and to decrease cost of 4-bar target needed to measured MRTD. However, use of multi-size 4-bar target in MRTD measurements is risky due to two reasons.

- First, the MRTD is a subjective parameter that is determined on human decision what is temperature difference needed to produce image when the observer can resolve bars of the 4-bar target. The measured MRTD can be the best (the lowest MRTD value) when test system projects an image of a single 4-bar target on an uniform background. Interference between two 4-bar patterns of the same spatial frequency but of different orientation is minimal but interference between several 4-bar patterns of different spatial frequency (size) can be strong. Practically it means that presence of a series of 4-bar patterns of different spatial frequency (size) can distract observer and change measurement results comparing to situation of a single 4-bar pattern on uniform background.
- Second, resolution of tested thermal imagers is the best in center of their FOV. Therefore MRTD measurement results when multi-size 4-bar targets having patterns located at significant distance from the center can be

different comparing to situation when the same 4-bar pattern is located at the center of FOV.

These are very significant drawbacks and therefore Inframet generally recommends typical multi-size 4-bar targets only preliminary fast evaluation of resolution of thermal imager. They are not recommended for accurate MRTD measurements.

However, there is an exception from this rule: slanted multi-size dual orientation 4-bar targets (see Table 2e). There are still several dual orientation 4-bar patterns on the target plate but these patterns are slanted. Due to rotation of the rotary wheel only the active pattern for which MRTD measurement is done is non-slanted and is in center of imager FOV. Human eye is very sensitive to detect slanted images and brain can concentrates easily to analyse image of non-slanted 4-bar pattern.

This solution presents a series of advantages:

1. Active pattern under tests is located approximately in center of FOV of tested imager,
2. High measurement speed of MRTD as patterns of both vertical and horizontal orientations are visible (both vertical MRTD and horizontal MRTD can be measured at the same time),
3. Higher number of 4-bar resolution patterns in targets inserted to a rotary wheel because several 4-bar patterns can be located on a single target plane.

Therefore Inframet uses this special type of multi-size 4-bar targets for MRTD measurements. However, it should be noted that slanted multi-size dual orientation 4-bar target is possible only in cases of when 4-bar patterns are much smaller comparing to total target plate area. Practically this feature limits application for high spatial frequencies over about 1 lp/mm.

8 Edge targets

Edge targets are typically manufactured to have a single hole in metal sheet in form of a semi-moon or semi-square. The latter shape has advantage of larger area on both sided of the edge that can be analyzed.

These targets are used in measurements of modulation transfer function – MTF – of thermal imagers to simulate step change of temperature. Inframet offers edge targets having local deviation from straight line at level below 2 µm. It is a sharp contrast to typical edge targets cut from thin metal sheets using laser technology when the deviation can be as high as 10 µm and this non perfect shape of the edge can influence measurement results.

The edge targets are typically delivered as so called slanted edge target. It means that the edge line is slightly rotated by an angle about 5º relative to vertical/horizontal planes. This slanting is needed to enable subpixel sampling of edge image during MTF calculation.

9 Dot cross targets

Dot cross targets are used to create, after they are fixed at collimator focal plane, images of known angular size. Imager of these targets generated by tested imagers are analyzed by software and FOV and distortion are measured.

10 Aim cross targets

Aim cross targets are used to show point for tested thermal sight that should be indicated by aiming sign of this imager. The aim cross pattern is manufactured by cutting four bars and central dot as shown in Table 1d. Aim cross targets are available in several different sizes.

11 IR USAF1951 targets

IR USAF1951 target (see Table 1e) is a version of popular USAF1951 resolution target. The latter target is typically manufactured by printing an array of non transparent 3-bar patterns on chromium coating on glass substrate using photolithography methods. IR USAF1951 targets are manufactured by cutting holes in thin metal sheet. Due to this difference typical USAF1951 can generate image only for imagers working in glass transmission range (visible, near infrared, partially SWIR, partially UV) when IR USAF1951 target can generate image for imagers working in any optical spectrum including spectral band of thermal imagers: MWIR-LWIR.

IR USAF1951 target is an excellent tool for fast evaluation of image quality and preliminary measurement of resolution of thermal imagers due to short measurement time. However, it is not recommended for accurate measurement of MRTD for reasons stated in Section 7 (it can be treated as a multi-size dual rotation 3-bar target).

Inframet manufactures two types of IR USAF1951 target:

1. IR USAF1951A target: resolution patterns from group 0 element 1 to group 3 element 3 (spatial frequency range from 1 lp/mm to 10.08 lp/mm),
2. IR USAF1951B target: resolution patterns from group 2 element 1 to group 4 element 6 (spatial frequency range from 4 lp/mm to 28.5 lp/mm).

12 Angular parameters of IR targets

IR targets are typically used as blocks of image projectors. They are located at collimator focal plane and combined with an area blackbody located just behind the target generate image of a reference target of required shape in thermal spectral band (MWIR-LWIR). The angular properties of projected image depend not only on linear dimensions of the hole in the IR target but also on collimator focal length. Therefore the same IR target can generate a series of reference images of of different angular properties.

Three angular parameters are used to characterize angular properties of projected image: spatial frequency, angular size and more rarely inverse angular size.

Spatial frequency is a parameter used to characterize periodic targets like 4-bar targets of 3-bar targets (IR USAF1951 targets). The spatial frequency is a measure of how often periodic function (sinusoidal or rectangular) repeat per unit of angle.

The spatial frequency **ν** (in line pair per mrad unit) of image of 4-bar target (or IR USAF1951 target) located at collimator focal plane of typical image projector can be calculated as

$$\nu=\frac{f'}{(2a)} \tag{1}$$

where ***f'*** is focal length of the collimator in meter unit, and ***a*** is bar width of the 4-bar target in milimeter unit.

Angular size and inverse angular size are used to characterize non periodic targets: pinhole, triangle, square, cross, slit, silhouette.

Target angular size ***α*** in mrad unit is calculated as

$$\alpha=\frac{a}{f'} \tag{2}$$

where ***a*** is target linear size in mm unit and ***f'*** is focal length of the collimator in meter unit.

Inverse target angular size is calculated as inverse of formula 2.

Attention:

Equivalent target angular sizes or equivalent inverse angular size are sometimes used to characterize targets angular properties of triangle/pinhole targets when measuring TOD or MDTD. These are angular parameters of equivalent square of area equal to are of target of interest of different shape. However, this document refer to real angular properties of targets of interest.

13 Dimensional specifications of typical IR targets

This section presents basic technical specifications of typical IR targets manufactured by Inframet.

The patterns on IR target plates can be manufactured on metal sheets of following areas

1. circle of diameter 42mm or square 42x42mm (solution optimized for TCB-2D blackbody of emitter 50x50mm),
2. circle of diameter 70mm or square 70x70mm (solution optimized for TCB-4D blackbody of emitter 100x100mm),
3. circle of diameter 105mm or square 110x110mm (solution optimized for TCB-6D blackbody of emitter 150x150mm).

The first case should be treated as standard used in over 95% of Inframet test systems. The second case is used sometimes in systems built using collimators of long focal length over 1500mm. The third case is used sometimes in systems built using collimators of very long focal length over 4000mm. The solutions 2-3 are treated as optional.

The data presented below refer to typical targets or active area diameter 42mm or square 42x42mm (solution optimized for TCB-2D blackbody of emitter 50x50mm).

13.1 4-bar targets

Inframet manufacturers of long series of 4-bar targets of different spatial frequencies. List of spatial frequencies of typical 4-bar patterns is shown in table below.

Table 3. Spatial frequencies of typical four bar patterns of specified bar width [mm] for collimators of different focal length [mm]

bar width [mm]	**Collimator focal length [mm]**													
	f’600	**f’800**	**f’1000**	**f’1200**	**f’1500**	**f’1600**	**f’2000**	**f’2400**	**f’2500**	**f’3000**	**f’3500**	**f’4000**	**f’5000**	**f’6000**
8,0								0,15	0,16	0,19	0,22	0,25	0,31	0,38
6,5								0,18	0,19	0,23	0,27	0,31	0,38	0,46
5,0			0,10	0,12	0,15	0,16	0,20	0,24	0,25	0,30	0,35	0,40	0,50	0,60
4,0	0,08	0,10	0,13	0,15	0,19	0,20	0,25	0,30	0,31	0,38	0,44	0,50	0,63	0,75
3,36	0,09	0,12	0,15	0,18	0,22	0,24	0,30	0,36	0,37	0,45	0,52	0,60	0,74	0,89
2,83	0,11	0,14	0,18	0,21	0,27	0,28	0,35	0,42	0,44	0,53	0,62	0,71	0,88	1,06
2,38	0,13	0,17	0,21	0,25	0,32	0,34	0,42	0,50	0,53	0,63	0,74	0,84	1,05	1,26
2,00	0,15	0,20	0,25	0,30	0,38	0,40	0,50	0,60	0,63	0,75	0,88	1,00	1,25	1,50
1,68	0,18	0,24	0,30	0,36	0,45	0,48	0,60	0,71	0,74	0,89	1,04	1,19	1,49	1,79
1,41	0,21	0,28	0,35	0,43	0,53	0,57	0,71	0,85	0,89	1,06	1,24	1,42	1,77	2,13
1,19	0,25	0,34	0,42	0,50	0,63	0,67	0,84	1,01	1,05	1,26	1,47	1,68	2,10	2,52
1,00	0,30	0,40	0,50	0,60	0,75	0,80	1,00	1,20	1,25	1,50	1,75	2,00	2,50	3,00
0,84	0,36	0,48	0,60	0,71	0,89	0,95	1,19	1,43	1,49	1,79	2,08	2,38	2,98	3,57
0,71	0,42	0,56	0,70	0,85	1,06	1,13	1,41	1,69	1,76	2,11	2,46	2,82	3,52	4,23
0,59	0,51	0,68	0,85	1,02	1,27	1,36	1,69	2,03	2,12	2,54	2,97	3,39	4,24	5,08
0,50	0,60	0,80	1,00	1,20	1,50	1,60	2,00	2,40	2,50	3,00	3,50	4,00	5,00	6,00
0,42	0,71	0,95	1,19	1,43	1,79	1,90	2,38	2,86	2,98	3,57	4,17	4,76	5,95	7,14
0,35	0,86	1,14	1,43	1,71	2,14	2,29	2,86	3,43	3,57	4,29	5,00	5,71	7,14	8,57
0,30	1,00	1,33	1,67	2,00	2,50	2,67	3,33	4,00	4,17	5,00	5,83	6,67	8,33	10,00
0,25	1,20	1,60	2,00	2,40	3,00	3,20	4,00	4,80	5,00	6,00	7,00	8,00	10,00	12,00
0,21	1,43	1,90	2,38	2,86	3,57	3,81	4,76	5,71	5,95	7,14	8,33	9,52	11,90	14,29
0,18	1,67	2,22	2,78	3,33	4,17	4,44	5,56	6,67	6,94	8,33	9,72	11,11	13,89	16,67
0,15	2,00	2,67	3,33	4,00	5,00	5,33	6,67	8,00	8,33	10,00	11,67	13,33	16,67	20,00
0,12	2,50	3,33	4,17	5,00	6,25	6,67	8,33	10,00	10,42	12,50	14,58	16,67	20,83	25,00
0,10	3,00	4,00	5,00	6,00	7,50	8,00	10,00	12,00	12,50	15,00	17,50	20,00	25,00	30,00
0,08	3,75	5,00	6,25	7,50	9,38	10,00	12,50	15,00	15,63	18,75	21,88	25,00	31,25	37,50
0,06	5,00	6,67	8,33	10,00	12,50	13,33	16,67	20,00	20,83	25,00	29,17	33,33	41,67	50,00
0,05	6,00	8,00	10,00	12,00	15,00	16,00	20,00	24,00	25,00	30,00	35,00	40,00	50,00	60,00
0,045	6,67	8,89	11,11	13,33	16,67	17,78	22,22	26,67	27,78	33,33	38,89	44,44	55,56	66,67
0,040	7,50	10,00	12,50	15,00	18,75	20,00	25,00	30,00	31,25	37,50	43,75	50,00	62,50	75,00
0,035	8,57	11,43	14,29	17,14	21,43	22,86	28,57	34,29	35,71	42,86	50,00	57,14	71,43	85,71
0,030	10,00	13,33	16,67	20,00	25,00	26,67	33,33	40,00	41,67	50,00	58,33	66,67	83,33	100,00
0,026	11,54	15,38	19,23	23,08	28,85	30,77	38,46	46,15	48,08	57,69	67,31	76,92	96,15	115,38
0,023	13,00	17,39	21,74	26,09	32,61	34,78	43,48	52,17	54,35	65,22	76,09	86,96	108,70	130,43
0,020	15,00	20,00	25,00	30,00	37,50	40,00	50,00	60,00	62,50	75,00	87,50	100,00	125,00	150,00

Attentions:

1. Inframet can manufacture 4-bar patterns of spatial frequency not listed in table above. There is no big price differences between typical 4-bar patterns and customized 4-bar patterns.
2. If it is possible then it is recommended to use collimators of longer focal length in order to be able to use 4-bar patterns of bar width over about 0.05mm because smaller targets are made from very thin metal sheet and are thermally less stable.

13.2 Edge targets

Inframet manufactures following edge targets:

1. semi-moon of edge length 35mm (edge semi-moon 35mm)
2. semi-square of edge length 30mm (edge semi-square 30 mm)
3. semi-square of edge length 40 mm (edge semi-square 40 mm).

The targets are typically delivered in slanted edge version. The rotation angle relative to vertical/horizontal plane is 5º.

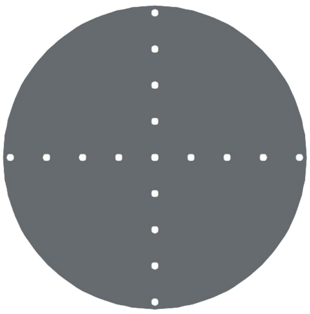
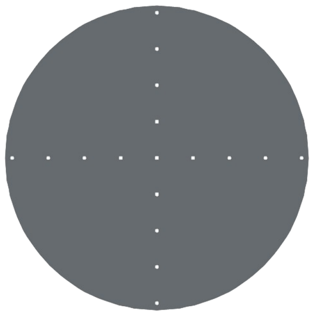
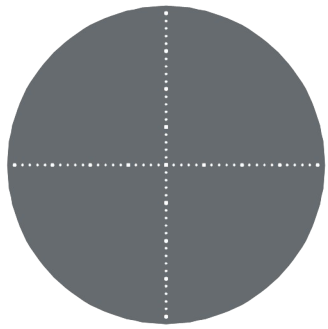
13.3 Dot cross targets

Dot cross targets are targets having pattern made from circular holes that create cross. Inframet manufactures dot cross targets of parameters as in tables below.

Table 4. Specifications of dot cross targets

Target code	Number of primary holes in the bar	Separation of primary holes [mm]	Diameter of primary holes [mm]	Number of secondary holes between the primary holes	Separation of secondary holes	Diameter of secondary hole [mm]
Dot cross 1	9	5	1	-	-	-
Dot cross 2	9	5	0.4	-	-	-
Dot cross 3	9	5	0.4	4	1	0.25

Table 5. View of dot cross targets

Dot cross 1	Dot cross 2	Dot cross 3
		

Angular dimensions in mrad unit of values listed in Table 4 can be calculated by dividing linear dimension in mm unit by collimator focal length in meter unit.

Targets of different dimensional parameters can be manufactured, too.

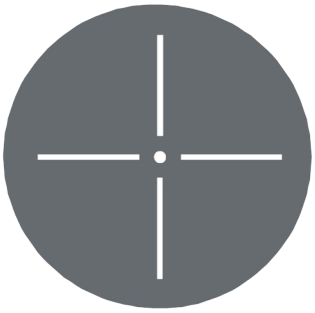
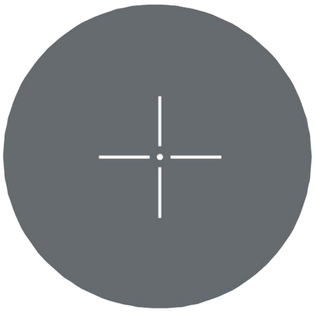
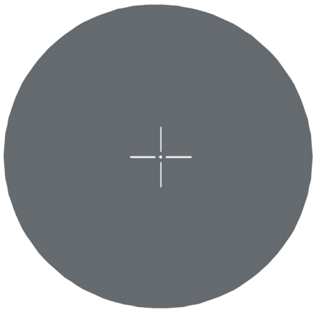
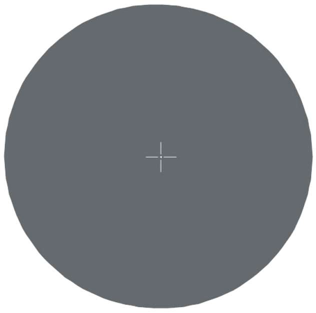
13.4 Aim cross targets

Inframet offers four typical aim crosses of specifications listed in Table 6 and visualization in Table 7.

Table 6. Specifications of typical aim cross targets

Target code	Diameter of center dot [mm]	Bar width [mm]	Bar length [mm]	Distance between bars [mm]
Aim cross 1.6	1.6	0.8	14	6
Aim cross 0.8	0.8	0.4	7	3
Aim cross 0.4	0.4	0.2	3.5	1.5
Aim cross 0.2	0.2	0.1	1.8	0.8

Table 7. View of aim cross targets

Aim cross 1.6	Aim cross 0.8	Aim cross 0.4	Aim cross 0.2
			

Angular dimensions in mrad unit of values listed in Table 6 can be calculated by dividing linear dimension in mm unit by collimator focal length in meter unit.

Targets of different dimensional parameters can be manufactured, too.

13.5 Pinhole targets

Inframet manufacturers a series of pinhole patterns of different angular sizes. List of angular sizes of typical pinhole patterns is shown in table below.

Table 8. Angular sizes of typical pinhole patterns of specified diameter [mm] for collimators of different focal length [mm]

dia-meter [mm]	**Collimator focal length [mm]**													
	f'600	**f'800**	**f'1000**	**f'1200**	**f'1500**	**f'1600**	**f'2000**	**f'2400**	**f'2500**	**f'3000**	**f'3500**	**f'4000**	**f'5000**	**f'6000**
25,6	42,67	32,00	25,60	21,33	17,07	16,00	12,80	10,67	10,24	8,53	7,31	6,40	5,12	4,27
12,8	21,33	16,00	12,80	10,67	8,53	8,00	6,40	5,33	5,12	4,27	3,66	3,20	2,56	2,13
6,4	10,67	8,00	6,40	5,33	4,27	4,00	3,20	2,67	2,56	2,13	1,83	1,60	1,28	1,07
3,2	5,33	4,00	3,20	2,67	2,13	2,00	1,60	1,33	1,28	1,07	0,91	0,80	0,64	0,53
1,6	2,67	2,00	1,60	1,33	1,07	1,00	0,80	0,67	0,64	0,53	0,46	0,40	0,32	0,27
0,8	1,33	1,00	0,80	0,67	0,53	0,50	0,40	0,33	0,32	0,27	0,23	0,20	0,16	0,13
0,4	0,67	0,50	0,40	0,33	0,27	0,25	0,20	0,17	0,16	0,13	0,11	0,10	0,08	0,07
0,2	0,333	0,250	0,200	0,167	0,133	0,125	0,100	0,083	0,080	0,067	0,057	0,050	0,040	0,033
0,1	0,167	0,125	0,100	0,083	0,067	0,063	0,050	0,042	0,040	0,033	0,029	0,025	0,020	0,017
0,05	0,0833	0,0625	0,0500	0,0417	0,0333	0,0313	0,0250	0,0208	0,0200	0,0167	0,0143	0,0125	0,0100	0,0083
0,03	0,0417	0,0313	0,0250	0,0208	0,0167	0,0156	0,0125	0,0104	0,0100	0,0083	0,0071	0,0063	0,0050	0,0042
0,03	0,0500	0,0375	0,0300	0,0250	0,0200	0,0188	0,0150	0,0125	0,0120	0,0100	0,0086	0,0075	0,0060	0,0050
0,02	0,0333	0,0250	0,0200	0,0167	0,0133	0,0125	0,0100	0,0083	0,0080	0,0067	0,0057	0,0050	0,0040	0,0033

Targets of different dimensional parameters can be manufactured, too.

13.6 Triangle targets

Inframet manufacturers a series of triangle patterns of different angular sizes. List of angular sizes of typical triangle patterns is shown in table below.

Table 9. Angular sizes of typical triangle patterns of specified side size [mm] for collimators of different focal length [mm]

side [mm]	Collimator focal length [mm]													
	f'600	**f'800**	**f’1000**	**f’1200**	**f'1500**	**f’1600**	**f'2000**	**f'2400**	**f'2500**	**f'3000**	**f'3500**	**f’4000**	**f’5000**	**f’6000**
20,0	33,33	25,00	20,00	16,67	13,33	12,50	10,00	8,33	8,00	6,67	5,71	5,00	4,00	3,33
10,0	16,67	12,50	10,00	8,33	6,67	6,25	5,00	4,17	4,00	3,33	2,86	2,50	2,00	1,67
5,0	8,33	6,25	5,00	4,17	3,33	3,13	2,50	2,08	2,00	1,67	1,43	1,25	1,00	0,83
2,5	4,17	3,13	2,50	2,08	1,67	1,56	1,25	1,04	1,00	0,83	0,71	0,63	0,50	0,42
1,25	2,08	1,56	1,25	1,04	0,83	0,78	0,63	0,52	0,50	0,42	0,36	0,31	0,25	0,21
1,00	1,67	1,25	1,00	0,83	0,67	0,63	0,50	0,42	0,40	0,33	0,29	0,25	0,20	0,17
0,75	1,25	0,94	0,75	0,63	0,50	0,47	0,38	0,31	0,30	0,25	0,21	0,19	0,15	0,13
0,50	0,83	0,625	0,500	0,417	0,333	0,313	0,250	0,208	0,200	0,167	0,143	0,125	0,100	0,083
0,25	0,42	0,313	0,250	0,208	0,167	0,156	0,125	0,104	0,100	0,083	0,071	0,063	0,050	0,042
0,12	0,20	0,150	0,120	0,100	0,080	0,075	0,060	0,050	0,048	0,040	0,034	0,030	0,024	0,020

Targets of different dimensional parameters can be manufactured, too.

13.7 Slit targets

Inframet manufacturers a series of slit patterns of different angular sizes. List of angular sizes of typical slit patterns is shown in table below.

Table 10. Angular sizes of typical slit patterns of specified slit width [mm] for collimators of different focal length [mm]

dia-meter [mm]	Collimator focal length [mm]													
	f'600	**f'800**	**f’1000**	**f’1200**	**f'1500**	**f’1600**	**f'2000**	**f'2400**	**f'2500**	**f'3000**	**f'3500**	**f’4000**	**f’5000**	**f’6000**
15,0	25,00	18,75	15,00	12,50	10,00	9,38	7,50	6,25	6,00	5,00	4,29	3,75	3,00	2,50
10,0	16,67	12,50	10,00	8,33	6,67	6,25	5,00	4,17	4,00	3,33	2,86	2,50	2,00	1,67
7,1	11,83	8,88	7,10	5,92	4,73	4,44	3,55	2,96	2,84	2,37	2,03	1,78	1,42	1,18
5,0	8,33	6,25	5,00	4,17	3,33	3,13	2,50	2,08	2,00	1,67	1,43	1,25	1,00	0,83
3,5	5,83	4,38	3,50	2,92	2,33	2,19	1,75	1,46	1,40	1,17	1,00	0,88	0,70	0,58
2,5	4,17	3,13	2,50	2,08	1,67	1,56	1,25	1,04	1,00	0,83	0,71	0,63	0,50	0,42
1,8	3,000	2,250	1,800	1,500	1,200	1,125	0,900	0,750	0,720	0,600	0,514	0,450	0,360	0,300
1,25	2,083	1,563	1,250	1,042	0,833	0,781	0,625	0,521	0,500	0,417	0,357	0,313	0,250	0,208
0,84	1,400	1,050	0,840	0,700	0,560	0,525	0,420	0,350	0,336	0,280	0,240	0,210	0,168	0,140
0,59	0,9833	0,7375	0,5900	0,4917	0,3933	0,3688	0,2950	0,2458	0,2360	0,1967	0,1686	0,1475	0,1180	0,0983
0,42	0,7000	0,5250	0,4200	0,3500	0,2800	0,2625	0,2100	0,1750	0,1680	0,1400	0,1200	0,1050	0,0840	0,0700
0,03	0,0500	0,0375	0,0300	0,0250	0,0200	0,0188	0,0150	0,0125	0,0120	0,0100	0,0086	0,0075	0,0060	0,0050
0,02	0,0333	0,0250	0,0200	0,0167	0,0133	0,0125	0,0100	0,0083	0,0080	0,0067	0,0057	0,0050	0,0040	0,0033

Targets of different dimensional parameters can be manufactured, too.

13.8 Manufacturing tolerances

Inframet manufactures IR targets with tolerances listed below.

Table 11. Manufacturing tolerances of IR targets

Target Type	Critical parameter	Minimal dimension	Manufacturing uncertainty
4 bar	Bar width	0.02	±4% + 6μm for size over 0.300 mm ±4% + 4μm for size range 0.050 ÷ 0.030 mm ±2% + 2μm for size below 0.050 mm
IR USAF1951	Bar width	0.035	
Dot cross	Diameter dots	0.2	
Aim cross	Bar width	0.3	
Pinhole	Diameter	0.05	
Slit	Bar width	0.42	
Triangle	Triangle edge	0.25	
Square	Square edge	1.6	
Silhouette	Minimum distance between edges	0.035	
Edge	Edge local non uniformity	-	1 μm local linearity for length below 1 mm

Version: 3.1

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