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Thermal Image for Truncated Object Target In The Presence of Vibrations Motions

Fadhil K. Fuliful   Rajaa Hussein.A.   Hind Kh.A.   Azhr Abdulzahraa Raheem
University of Karbala, College of Science, Department of Physics

Abstract
The effects of vibration (longitudinal &transverse) on thermal imaging for truncated object target are considered, a conventional thermal camera and a Mathcad program to reconstruct the Bar Spread Function (BSF) degraded because vibration of target .A aerial photography is used as application in imaging the target ,results indicates that even low amplitude vibration greatly affects the predicted target detection.

Introduction
The typical vehicles used in aerial photography are airplane and helicopter. However, the production image with these vehicles are expensive, aerial photography has wide applications in military, topographical mapping, engineering, environmental studies and exploration for oil. Image distortion caused by vibration motion is one of the most problems for a thermal imager. The reduction of image resolution due to image motion influences the ability of optical eyes to detect the target. The effects of sinusoidal image motion, which often results from mechanical vibrations, can be divided into longitudinal and transverse vibrations .A computational imaging system [1] that contains an optical position sensing detector array, a conventional camera and a method to predict the degraded of images by spatially variant platform motion blur. The vibration of the gyrocopter platform [2] is one of the critical factors that should be considered during the data collection, which are wind-induced oscillation, vibration induced by the motor, the propeller and the main rotor. To prevent negative effect to the imaging process, vibration absorbers are used on the sensor platform. Describing a general method for determining the distance of a point objects by measuring the degree of image blur, the method is more accurate for closest objects than for distant objects [3].A computational model for Synthetic aperture radar (SAR) [4] simulation of stable point targets was consider and mathematically define constant motion, acceleration and vibration of point targets as well as extended rotating objects. Results illustrated some important effects of moving targets. The presented model has flexibility. Image vibrations are a common parameter for imaging systems which are unstabilized for using for target detection purposes [5], the reduction of the probability of detection is affected by long distance targets and for large relative exposure interval. This result is illustrated by increasing the observer time for getting the target, the best case repeats itself many times so that the target will finally be acquired. It is clear that image motion and vibration can significantly affect target acquisition times and ranges. Flight conditions usually cause disturbance of image quality [6]. The modulation transfer functions (MTF) are convenient techniques for measuring the image quality of photographs. The MTF of the image forming system is the result of the contributions of the camera, the film, image motion (in systems without forward motion compensation, FMC), vibrations, and the atmosphere to produce images. The edge spread function (ESF)in the diffraction images of an incoherent object [7] has been evaluated in the presence of transverse and longitudinal sinusoidal vibrations, the obtained results illustrate graphically the degrading effects of vibrations on the quality of the optical image. The effect of linear motion on the diffraction image of truncated object was evaluated by calculating the degradation of intensity distribution for Bar image at different values of linear motion factor [8].
The aim of this paper is to apply Bar Spread Function (BSF) technique to analyze for target detection in the presence of vibration motion (longitudinal &transverse). The present Mathcad algorithms is used to calculate the intensity distribution of the object in two cases with and without vibration movement, the amplitude of vibration parameters dependent on the properties of thermal camera such as focal number as well as ranges and IR target wave length.

Theory:
The bar object is important in studies and scientific research because of its wide applications as aerial photography many forms as possible to be bar object, such as highways, railways and wires of electric power.
The bar object consists of a set of linear objects, where they can find complex amplitude in the image of bar using convolution theorem circumvents the complex amplitude in the object with the complex amplitude linear incision and using bypass [3] convolution integral we get:

$$T(z^{\backslash}) = \int_{-\infty}^{\infty} T(z).H(z^{\backslash} - z)dz \text{.......... ....(1)}$$

$H(z^{\backslash} - z)$: Complex of image amplitude line object
$T(z^{\backslash})$: Complex of image amplitude bar object

$$H(z^{\backslash} - z) = \int_y \int_x f(x,y).e^{i(z^{\backslash}-z)x}.e^{-i(z^{\backslash}-z)y} dx.dy \text{.........................(2)}$$

$$T(z^{\backslash}) = \int_y \int_x f(x,y)e^{iZ^{\backslash}(x-y)}.dxdy \int_{-\infty}^{\infty} T(z)e^{iZ^{\backslash}(x-y)}dz \text{.........................(3)}$$

$$\int_{-\infty}^{\infty} T(z)e^{-iz(x-y)}dz = t(x,y) \text{...........................(4)}$$

Where t(x,y) : spectrum of bar object defined as pupils enter the optical system.
the complex amplitude of the bar with width ($2d$) as follows :
t (Z) =1 when $d \le |Z|$
t (Z) =0 when $d > |Z|$
As:
$f(x,y) = e^{ikw(x,y)}$
By using mathematical method to simplify the equation get :

$$T(z^{\backslash}) = 2\left[\int_y \int_x \cos(z^{\backslash}(x-y) + kw(x,y))\right] \frac{\sin(x-y).d}{(x-y)} dx.dy + i\sin(z^{\backslash}(x-y) + kw(x,y))$$
$$\frac{\sin(x-y).d}{(x-y)} dx.dy \text{.........(5)}$$

$$B(z^{\backslash}) = \left|T(z^{\backslash})\right|^2$$

$$B(z^{\backslash}) = N\left\{\left[\left[\int_y \int_x \cos(z^{\backslash}(x-y) + kw(x,y))\right].\frac{\sin(x-y).d}{(x-y)} dx.dy\right]^2 + \left[\int_y \int_x \sin(z^{\backslash}(x-y) + kw(x,y))\frac{\sin(x-y).d}{(x-y)} dx.dy\right]\right\}^2$$
........(6)

Where Eq.6 represent Bar Spread Function
Where (N): is the normalization factor
The effect of mechanical vibration on defection target using thermal imager can be divided into transverse and longitudinal vibration movements, in the first case the Bar Spread Function become:

$$B(z^{\backslash}) = \frac{1}{\pi^2}\left\{\left[\int_y \int_x \cos(z^{\backslash}(x-y))\frac{\sin(x-y)d}{(x-y)} dx.dy\right]^2 J_O[\pi A(x-x_1)] + \left[\int_y \int_x \sin(z^{\backslash}(x-y))\frac{\sin(x-y)d}{(x-y)} dxdy\right]\right\}^2$$
$$J_O[\pi A(x-x_1)] \text{....................................(7)}$$
Where

$J_0[\pi A(x-x_0)]$ Is the transverse sinusoidal vibration is given by a zero-order Bessel function.

Where [7]: $A=\frac{2f\psi}{\lambda F}$

A: transverse vibration factor
f: focal length of the thermal camera (210 mm)
ψ: transverse vibration movement (mm)
λ: wave length of incident ray (10µm)
F: focal number can be found from thermal camera characteristics as:

$F=\frac{f}{D}$ Where D is the diameter of thermal camera (90 mm)

Then value of F is (2.233).

Let's consider now the simulation procedure which is depending on the value of factor (A) according the table (1)

Ψ mm	A
0.03	0.54
0.04	0.72
0.05	0.9
0.06	1.08
0.09	1.62
0.1	1.8

Table (1) characteristics of the search process (transverse vibration)

In the second case the Bar Spread Function becomes:

$$B(z)=\frac{1}{\pi^2}\left\{\left[\int_y\int_x \cos(z(x-y))\frac{\sin(x-y)d}{(x-y)}dx.dy\right]^2 J_O[\pi H\frac{(x-x_1)}{2}]+\left[\int_y\int_x \sin(z(x-y))\frac{\sin(x-y)d}{(x-y)}dxdy\right]\right\}^2$$

$$J_O[\pi H\frac{(x-x_1)}{2}]....................................(8)$$

Where [7]

L: longitudinal vibration movement.

The simulation in this case depends on the value of factor (H) as show in table (2)

$$H=\frac{L}{\lambda F^2}$$

L mm	H
0.1	2
0.2	4
0.3	6
0.4	8
0.5	10
0.6	12
0.7	14
0.8	16

Table (2) characteristics of the search process (longitudinal vibration)

Result and discussion:

To find the effect of mechanical vibrations on the intensity distribution of thermal image of truncated object, a certain cases for the target and the thermal camera are assumed. The assumption here is that the image vibration is the factor most limiting image quality. The vibration induced by the motors in different industries. Image motion reduces the overall (BSF) and therefore the reduction in the target acquisition probability for a given range and wave length. The reduction with resolution in the image plane as result of image vibrations affects the ability of imaging by aerial photography.

Figure (1) show that the intensity distribution of the Bar object image for different value of transverse vibration amplitude (0.03,0.04,0.05,0.06,0.09 and 0.1 mm) which gives the transverse vibration factor (A=0.54,0.72, ,0.90,1.08,1.62 and 1.80)respectively(see table 2) ,the image of Bar object or BSF with three values of (A= 0.54,0.72, and 0.90) are similar to the Bar image with (A=0) only the half width increased and the resolution power decrease , therefore the object can be detected, but the Bar image with value of (A = 1.08) is recognized only, also the images in cases (A=1.62 &1.80) are different when it compared with the image with (*A*=0),the peak value of (BSF) increased and shifted then the resolution power very decrease and the images are very bluer therefore the object cannot be detected. For increased the(Bar Half Width *d*=5,7)i.e. increased lightning as illustrated in the figures (2,3) when we use the same values of the factor (*A*),the image with values (0.54,0.72, ,0.90 and 1.08) also show degradation in intensity distribution for image because of decreasing in high intensity value and increasing in half width ,while the image is distortion and can't determine its properties in case of values (1.62 and 1.80) .

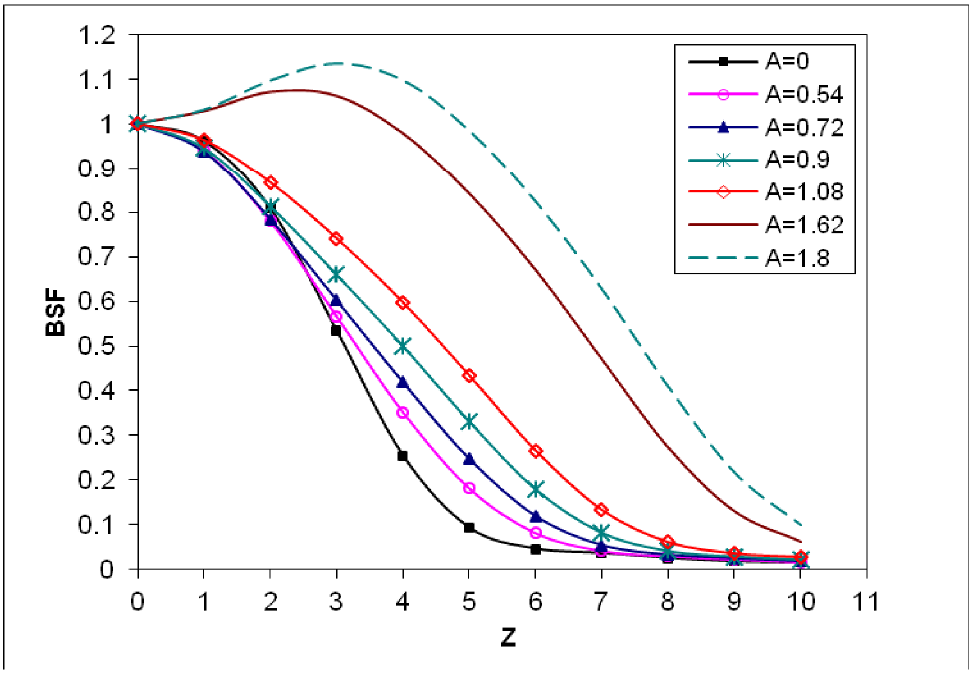

Figure (1) Thermal images of Bar object (d=3) with different value of (A)

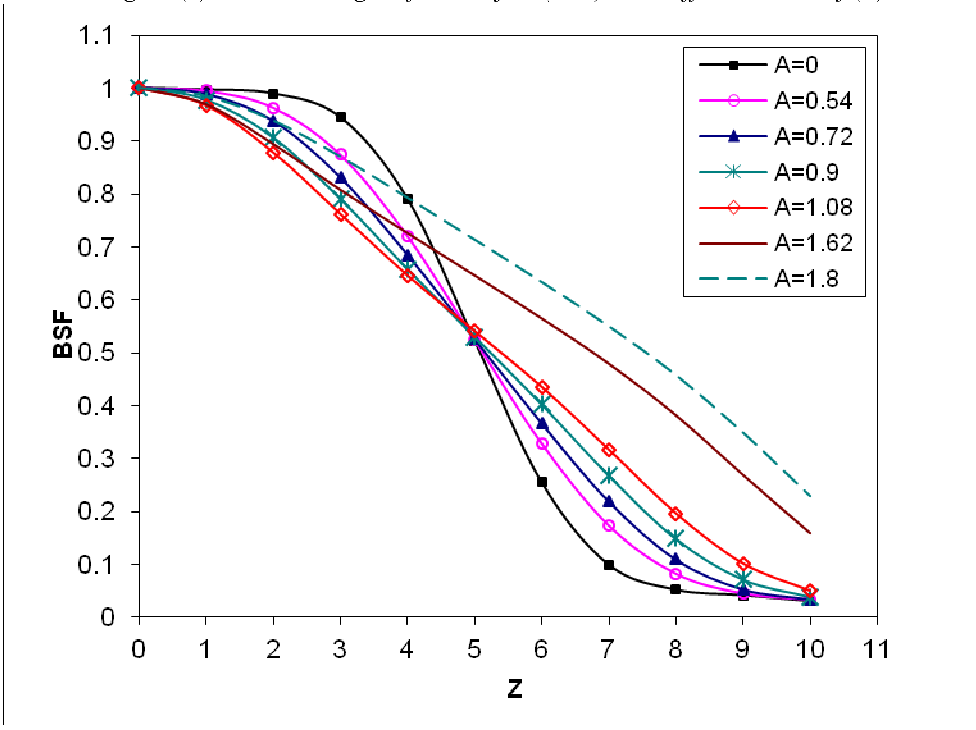

Fig. (2)Thermal images of Bar object (d=5) with different value of (A)

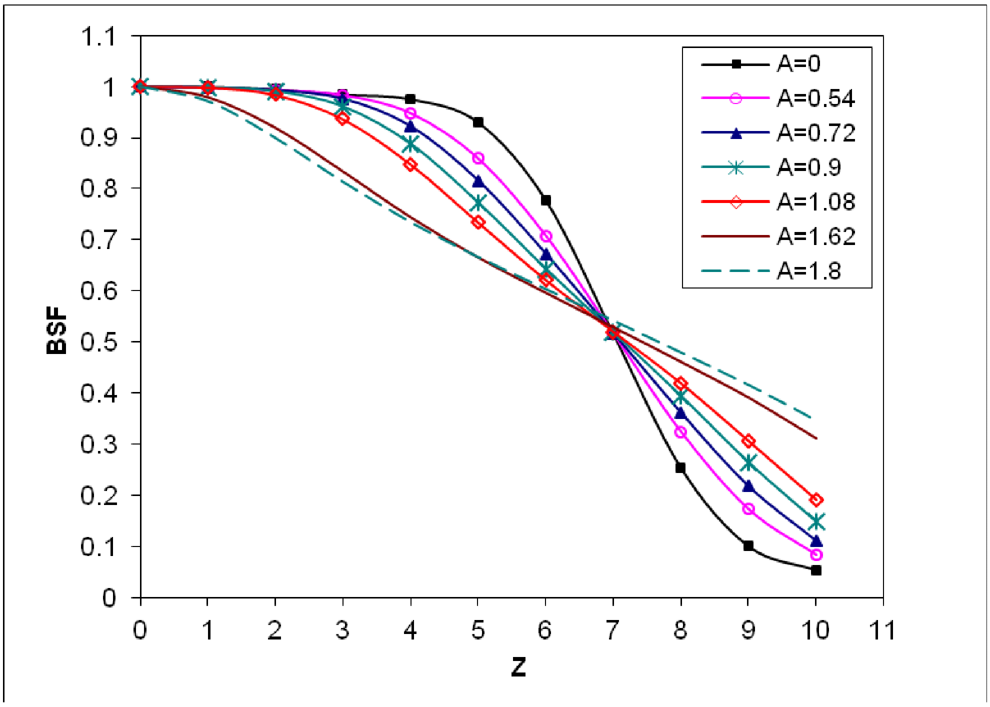

Fig. (3)Thermal images of Bar object (d=7) with different value of (A)

The effect of focus error (W_{20} =0.5) and transverse vibration factor (*A*) simultaneously on the images is shown in figures (4,5,6) figure(4) illustrated increasing of high intensity value in all cases as shown in the table (3) :

A	0	0.54	0.72	0.90	1.08	1.62	1.80
High intensity value	0.71958	0.73827	0.75627	0.7832	0.82051	0.97427	1.01667

Table (3) intensity distribution of (d=3)at different values of (A) and W_{20}*=o.5*

The comparison (table 3) give low resolution power in all images, the images for (*A*) with values (1.62, 1.8) has similar shapes of image with (*A*=0) although it's high values of intensities. Figures (5,6) show the intensity distribution of Bar image in case of increasing the lightning (*d*=5,7), the effects of transverse vibration factor and defocusing (W_{20} =0.5) are less on peak intensity value except slight increase in peak intensity value at (*A*=1.8 & *d*=5) (see table 4) ,therefore the BSF at values of transverse vibration factor (1.62,1.8) are very characterless.BSF in Figure (6) where (*d*=7) suffer the same effect, the comparison in table (4)(different values of *d*)show positive results at the intensity value (0.82501) in case (*d*=3).

Bar half width (*d*)	*A*=0	*A=1.08* W_{20}*=0.5*	*A*=1.62 W_{20}=0.5	*A*=1.8 W_{20}=0.5
3	0.71958	0.82501	0.97427	1.01667
5	0.8979	0.84248	0.87343	0.90349
7	0.95476	0.92679	0.88761	0.88149

Table (4) comparison of intensity distribution at different values of (d) and (A)

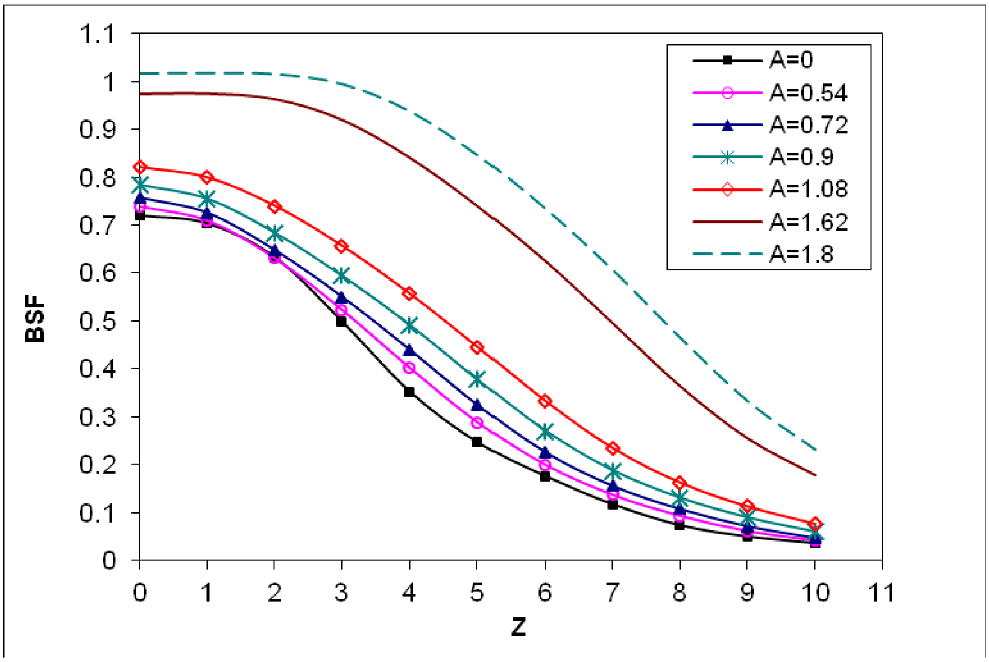

Fig. (4)Thermal images of Bar object (d=3) with different value of (A) and defocusing

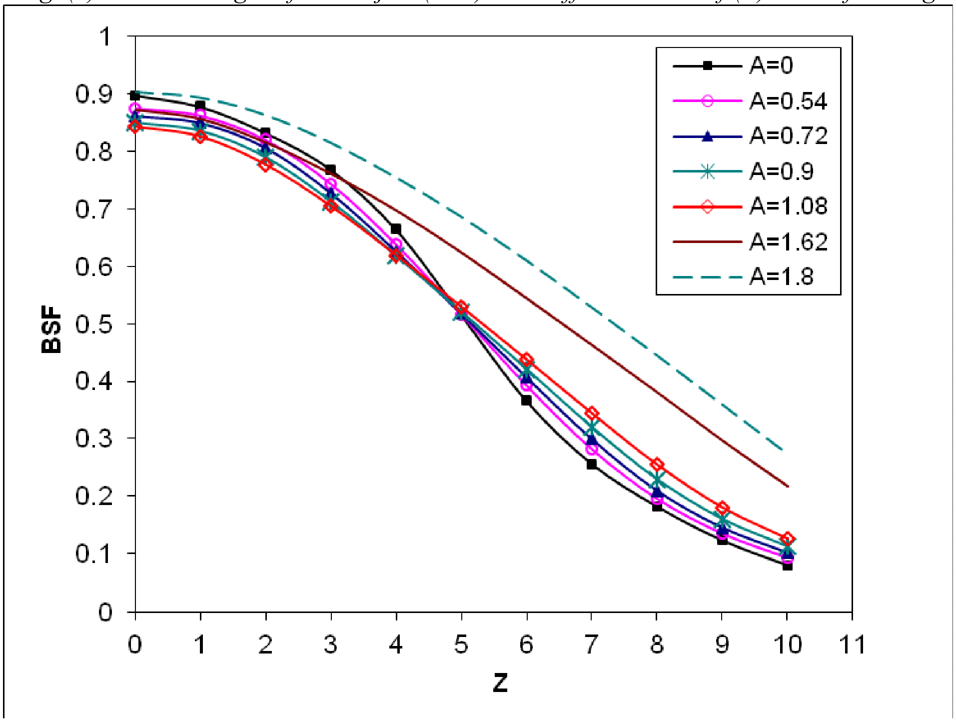

Fig. (5)Thermal images of Bar object (d=5) with different value of (A) and defocusing

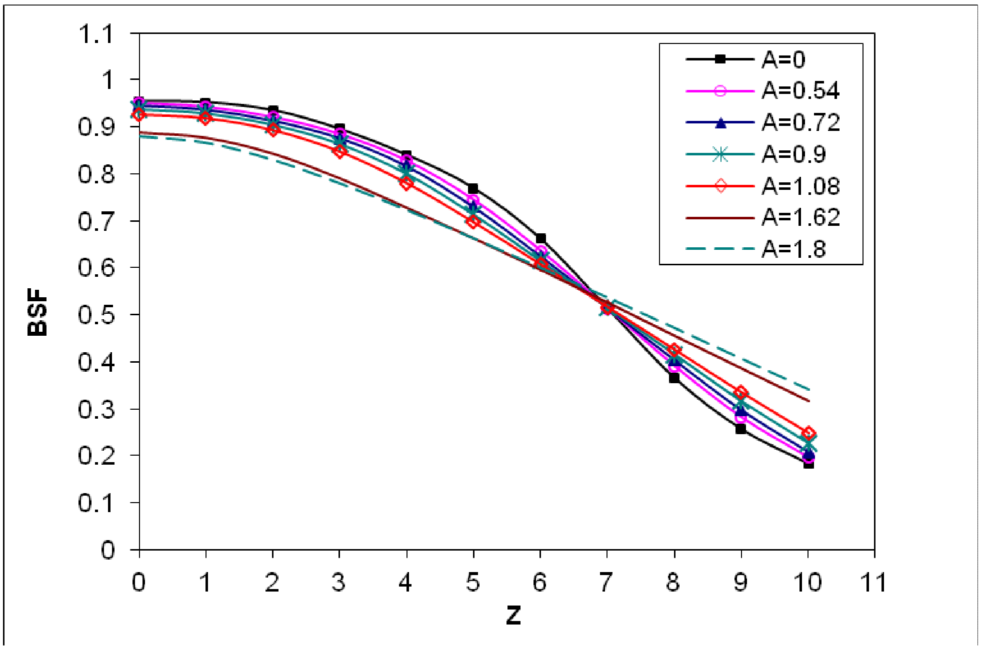

Fig. (6)Thermal images of Bar object (d=7) with different value of (A) and defocusing

The effect of longitudinal vibration factor (*H*) on (BSF) has been presented in Fig's (7,8,9) with values (2,4,6,8,10,12,14,16) ,all images in figure(7) have low resolution and intensity distribution of images with (*H*) values (2,4) has the same distribution in the case of (*H*=0) approximately while the other cases with (*H*) values (6,8,10,12,14,16) has effect on the (BSF) and the images are foggy. Fig.(8) shows image of Bar object (BSF) in case of (*d*=5) all curves has decreasing in peak intensity values also the degradation in intensity can be seen, only the BSF with (*H* = 2) has same shape of image with (*H*=0) and the BSF at (*H*) of values (4,6,8,10,12,14,16) give images cannot detect the object. Also the effect of longitudinal vibration factors on (BSF) in figure (9) as in figure (8).

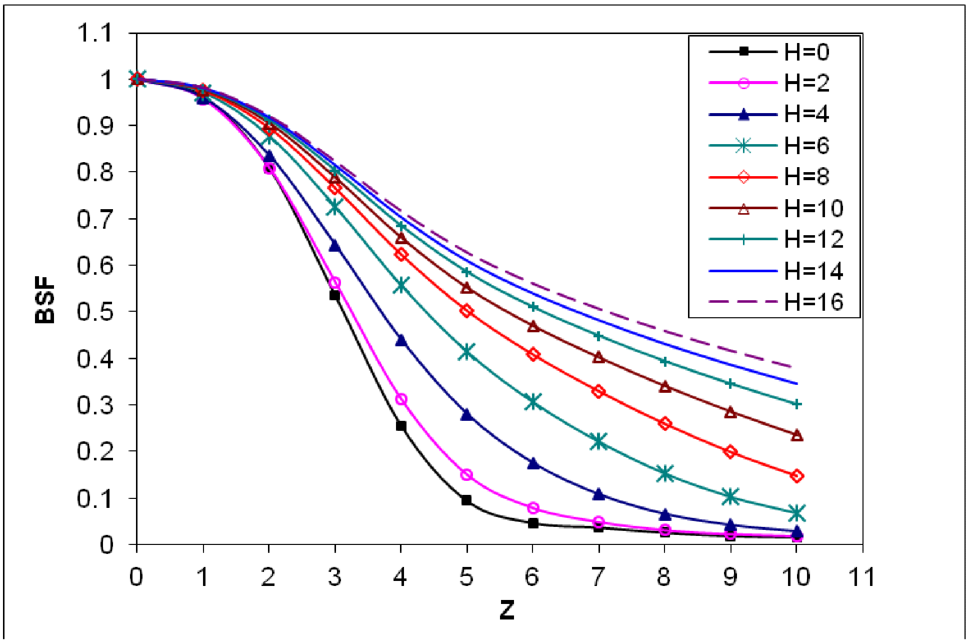

Fig. (7)Thermal images of Bar object (d=3) with different value of (H)

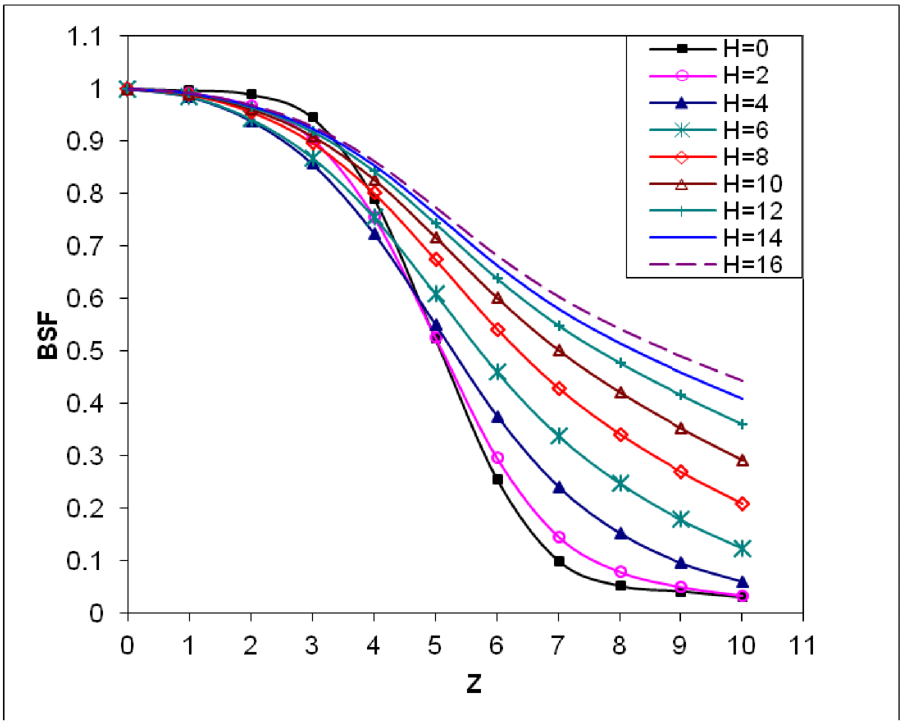

Fig. (8)Thermal images of Bar object (d=5) with different value of (H)

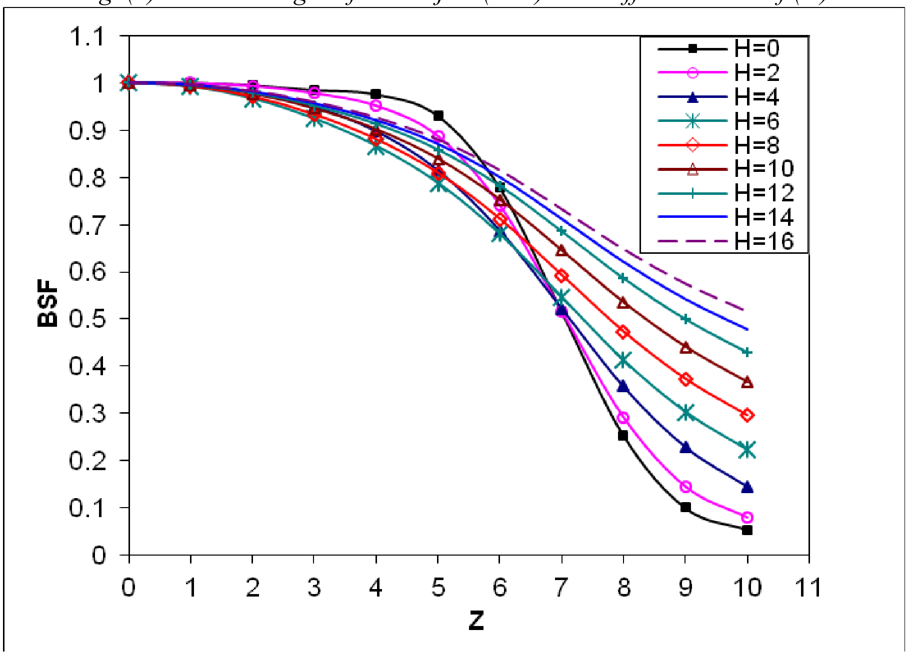

Fig. (9)Thermal images of Bar object (d=7) with different value of (H)

The influence of longitudinal vibration factors and defocusing (W_{20}) on (BSF) is shown in figures (10,11,12), the behavior of BSF shown in table (5),the results (d=3) illustrated the detection of object for (H = 2) and other values give low resolution then the object only recognized don't detected (see fig.10).Fig's (11,12) show low resolution ,therefore the thermal images of object are characterless and distortion because of decreasing in maximum intensity value.

Half width(d)	H=0	H=2 W_{20}=0.5	H=4 W_{20}=0.5	H=6 W_{20}=0.5	H=8 W_{20}=0.5	H=10 W_{20}=0.5	H=12 W_{20}=0.5	H=14 W_{20}=0.5	H=16 W_{20}=0.5
3	0.71958	0.7247	0.74053	0.76704	0.79338	0.81136	0.82456	0.83453	0.84235
5	0.8979	0.88821	0.87261	0.86919	0.87853	0.88973	0.8982	0.9049	0.91015
7	0.95476	0.95165	0.94134	0.9293	0.92525	0.92914	0.93439	0.93876	0.94243

Table (5) Effect of (H) and W20 on intensity distribution of Bar image (BSF)

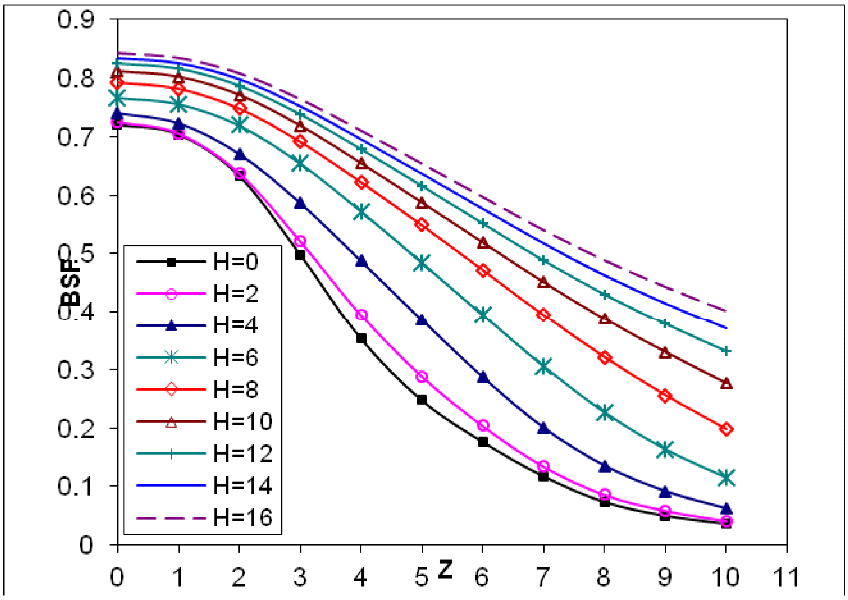

Fig. (10)Thermal images of Bar object (d=3) with different value of (H) and defocusing

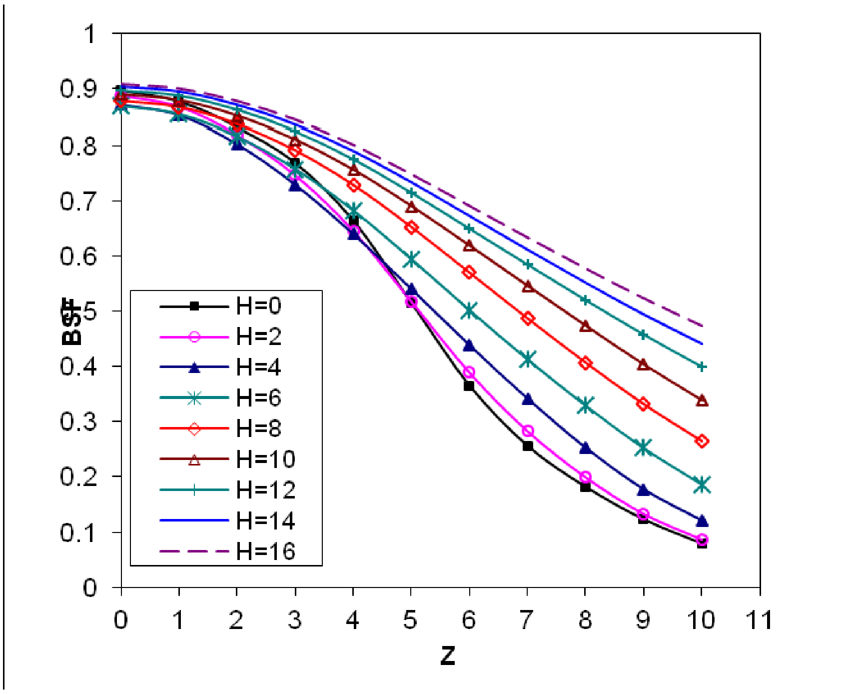

Fig. (11)Thermal images of Bar object (d=5) with different value of (H) and defocusing

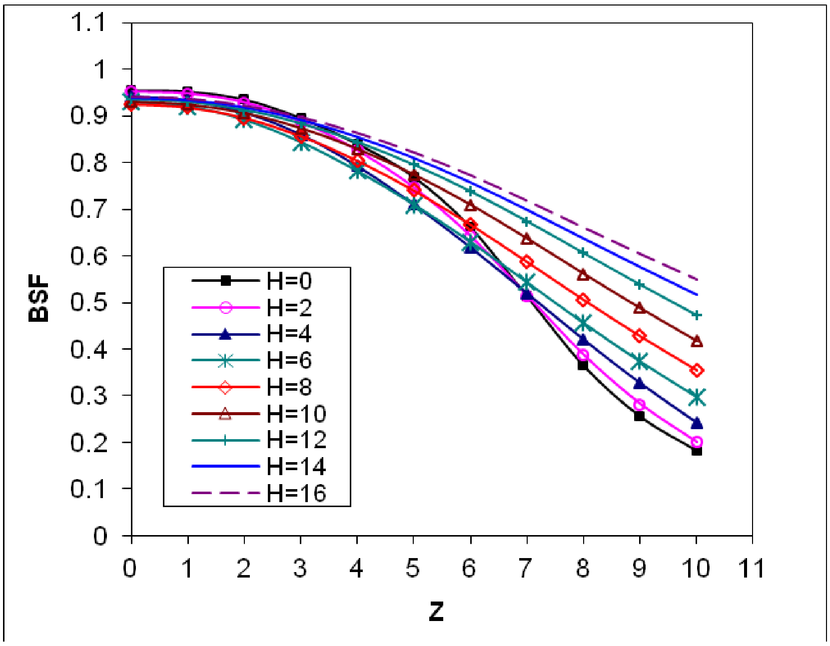

Fig. (12)Thermal images of Bar object (d=7) with different value of (H) and defocusing

Conclusion

1-The half width (d=3) of Bar object is acceptable and give thermal image with high resolution.
2-The effect of transverse vibration factor (*A*) on thermal image of a target (Bar object) depends on its values (*A*=0.54, 0.72, 0.90) the target can be detected but the value (*A*= 1.08) only recognized, while the values (*A*=1.62 &1.80) the target does not detect.
3- The effect of transverse vibration factor (*A*) and defocusing (W_{20}=0.5) simultaneously gives positive case at (*A*=1.08).
4-The effect of longitudinal vibration factor values (*H*) on the thermal images gives allowed values (H=2, 4) the target can be detected and the other values larger than it are not allowed because the target is undetectable.
5-The effect of longitudinal vibration factor (*H*) and defocusing (W_{20}=0.5) simultaneously gives added distortion.
5- As the amount of factors (*A&H*) is increased the intensity in the tail of curves (BSF) is increased (i.e. High distortion) this effect is clear in case of factor (*H*).
6- Transverse vibration factor are more damaging than longitudinal vibration factor.

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